VOLUME 28 NUMBER 2

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NEW YORK MEETING, DECEMBER 4-7, 1906

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PROCEEDINGS

NOVEMBER, 1906

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THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PROCEEDINGS

CONTAINING PAPERS
TO BE PRESENTED AT THE NEW YORK MEETING
DECEMBER 4-7, 1906

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PROCEEDINGS

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 28 NOVEMBER, 1906 NUMBER 2

BRING THIS COPY WITH YOU TO THE MEETING

The professional papers contained in this number of Proceedings are sent to you that you may prepare any discussion of them which you may wish to present. They are issued to the membership in confidence, and with the distinct understanding that they are not to be given to the press or to the public until after they have been presented at the meeting. All papers are subject to revision.

"The Society as a body is not responsible for the statements of facts or opinion advanced in papers or discussions." (C 55)

ANNUAL MEETING

Announcement was made in the October Proceedings to the effect that the Annual Meeting of the Society would be held in the new Engineering Building. This plan had been in mind for several months but it has been decided to avail ourselves once again of the hospitality of the New York Edison Company. The convention will, therefore, be held in the assembly rooms of the New York Edison Company, 44 West Twenty-seventh Street. Special arrangements have been made for the decoration of the rooms. The registration of members and guests this year will be taken care of by a large corps of special assistants working under Mr. Hoadley's direction. It is anticipated that the attendance will be in excess of the phenomenal attendance of last year.

INVITATION TO NON-MEMBERS

On account of the unusual interest in the enclosed program of the forthcoming meeting, December 4–7, 1906, in New York, the Society is sending the Proceedings to a number of engineers who it is thought will be pleased to attend.

To all persons receiving a copy of these Proceedings a cordial invitation is extended to be present throughout the meetings.

NATIONAL SOCIETY FOR INDUSTRIAL EDUCATION

Recognizing the great need for developing industrial education in the United States a number of men deeply interested in the subject, among whom are several members of this Society, have been for some months working towards the organization of a National Society for the Promotion of Industrial Education.

The plans of this committee are well forwarded towards completion and on the evening of Friday, November 16, a public meeting will be held at Cooper Union, which will be addressed among others by the following speakers: Hon. Frank A. Vanderlip, Vice-President of the City National Bank; Frederick P. Fish, Esq., President of the American Bell Telephone Co.; Miss Jane Addams, of Hull House, Chicago; Dr. Nicholas Murray Butler, President of Columbia University, and probably by Mr. Alfred Mosely, of London.

The committee extends a very cordial invitation to the members of The American Society of Mechanical Engineers to be present at this meeting and hopes that many will lend the influence of their presence to the launching of a movement which may well be pregnant with importance to the industries of the country.

Among the members of the Organization Committee are Messrs. Milton P. Higgins, Chairman, President, Norton Emery Wheel Co., Worcester; C. R. Richards, Secretary, Teachers' College, Columbia University; Henry S. Pritchett, President, Mass. Inst. Tech. M. W. Alexander; James P. Haney, Director of Manual Training, New York; Robert A. Woods, Director, South End House, Boston; Leslie W. Miller, Principal, Pennsylvania Museum and School of Industrial Art, Philadelphia; J. Ernest G. Yalden, Superintendent, Baron de Hirsch Trade School, New York; Charles L. Warner, Principal Technical High School, Springfield, Mass.; James P. Munroe; Arthur A. Hamerschlag, Director, Carnegie Technical Schools, Pittsburg; Louis Rouillion, Director, Franklin Union, Boston; Henry Bruère, Secretary, Bureau of City Betterment, Citizens' Union of the City of New York.

The orders for Revises for papers read at both the December (1905) and the Chattanooga (1906) meetings, have been filled. An unusually large number of cards ordering these papers were received without any name showing to whom the papers were to be sent. Except in a few instances it has been impossible for the office force to supply these names. In case any member who ordered papers has not received them this will probably account for it.

THE PHILADELPHIA CELEBRATION

The dedication of the new building of the Engineering Department of the University of Pennsylvania on Friday, October 19, proved to be a red letter occasion both for the engineering profession and for the Society.

The Society was officially represented by two of its most distinguished members, Mr. John Fritz and Mr. Frederick W. Taylor, the latter having been chosen for this honor after he had accepted an invitation from the University of Pennsylvania to make one of the two addresses on the occasion.

Four of our members, Mr. John Fritz, Mr. S. M. Vauclain, Mr. F. W. Taylor and Prof. H. W. Spangler, were honored by being given the degree of Doctor of Science. The Trustees in asking the Provost to confer the degrees pronounced the following summary of the life-work of each of the recipients:

JOHN FRITZ: Because it is given to few men to occupy a place in any profession such as he holds today. Respected by engineers throughout the world, full of years and of honors, he is the living exponent and exemplar of that band of forceful and sagacious men of a bygone generation to whose earnest labor and inventive genius the United States owes its present eminent position in the steel industry.

Identified from early manhood with the great pioneer iron works of the country, aiding materially in their building and development, the Nestor of the Bessemer process in America, we look with admiration on his career and admonish the youthful disciple of engineering to follow in his footsteps.

SAMUEL MATTHEWS VAUCLAIN: A vigorous mind and body combined with vast energy and endurance have enabled him to accomplish the work of more than one man in a short span of years. Courageous and resourceful, asking nothing of his fellows which he would not willingly perform himself, he has become a leader of men and a guiding spirit in an enterprise which directly supports a hundred thousand souls. Prolific in invention, far seeing, equally capable of grasping great projects and their smallest details, he has in large measure helped to build up an industry which will be a monument to his sagacity for a generation yet to come.

His contributions to the development of the steam locomotive have caused his name to be familiarly known wherever that useful pioneer of civilization has puffed its cheerful way.

FREDERICK WINSLOW TAYLOR: Thorough and industrious in preparation for his life work, patient in investigation and experiment,

logical in analysis and deduction, versatile in invention, his labors have brought system out of disorder in the organization and management of industrial establishments; and with his epoch-making discoveries in the arts of treating tool steel, and the cutting of metals, have enormously reduced the cost of production of machinery. A writer of distinction, The American Society of Mechanical Engineers has done well to make him its President.

HENRY WILSON SPANGLER: Educated at Annapolis, an Assistant Engineer in the United States Navy and a marked man in that organization, in 1881 he was assigned by the Government, at the request of the University of Pennsylvania, to act as instructor in the Towne Scientific School of the University. In 1883 he was made Assistant Professor of Mechanical and Electrical Engineering, and in 1890 full Professor. During the past 16 years he has fostered and guided his department to the commanding position which it now holds. He is responsible, with his colleague, Professor Marburg, for the interior arrangements and choice of equipment of this great building. He is beloved by student and graduate, respected by the officers of the University, a teacher of high renown, and a writer of authority in his profession.

The addresses, both by Members of the Society, were "A Comparison of University and Industrial Discipline and Methods," by Mr. Frederick W. Taylor, and "The Engineer as a Citizen," by Mr. Alex. C. Humphreys.

Among the other members of the Society in attendance were Mr. John R. Freeman, Prof. Frederick R. Hutton, Mr. James M. Dodge, Mr. Charles Whiting Baker, Mr. Fred J. Miller, Mr. Calvin W. Rice, Mr. Charles Day, and Mr. Kern Dodge.

The American Street and Interurban Railway Association held their Twenty-fifth Annual Convention at Columbus, Ohio, October 15 to 19.

In response to an invitation from the Association that the Society be represented at their Convention, there were designated as our representives, Mr. W. M. McFarland, Vice-President and Member of Council, Mr. E. M. Herr, Pittsburg, Pa., and Mr. H. G. Reist, Schenectady, N. Y. Under the By-laws these gentlemen were, by reason of this appointment, designated Honorary Vice-Presidents.

The Secretary calls especial attention to the program of the forthcoming meeting prepared by the Meetings Committee. When extraordinary effort is made to secure eminent men to contribute to our Proceedings, we bespeak for them a large attendance.

The President in his address will give the results of his life's experience in a work about which there is very little on record. The data, which will be complete in all details, are the actual results of 26 years of research and were obtained by an expenditure from first to last of upwards of $200,000.

The discussion on Wednesday morning will be participated in by many eminent authorities and specialists on the subject of cutting metals..

The Society has been looking forward with pleasant anticipation to holding the reception in the Engineering Building. We are disappointed in this, but instead, it will be held, as formerly, at Sherry's. The reception room has been enlarged and we are promised all possible comforts so that this distinctively social function of the New York meeting will be especially enjoyable.

For the excursion on Thursday, the Secretary has great satisfaction in announcing that through the courtesy of Mr. W. J. Wilgus, Vice-President of the N.Y.C. & H. R.R. Co., the members of the Society will be the guests of that company. We will enter cars at Grand Central station and proceed on one of the company's new trains, propelled by an electric locomotive, to the power station at Port Morris.

This will afford all an opportunity to inspect and become familiar with what is latest and most important in the engineering world.

CHANGE IN BY-LAWS

At the Chattanooga meeting the Secretary reported for record a change which has been ordered and approved by the Council under the provisions of Article C 59, concerning amendments to the By-Laws. By-Law B 21 formerly read as follows:

FINANCIAL ADMINISTRATION

B 21 The Council at its first meeting in each fiscal year shall consider the recommendations of the Finance Committee concerning the expenditure necessary for the work of the Society during that year. The apportioning of the work of the Society among the various Standing and other Committees shall be on a basis approved by the Council and in harmony with the Constitution and By-Laws. The appropriations approved by the Council, or so much thereof as may be required for the work of the Society, shall be expended by the various Committees of the Society, and all bills against the Society for such expenditures shall be certified by the Committee making the expenditure and shall then be sent to the Finance Committee for audit. Money shall not be paid out by any officer or employé of the Society except upon bills duly audited by the Finance Committee, or by resolution of the Council.

The Council has directed an amendment which makes this By-Law read as follows, beginning with the words "appropriations approved":

"The appropriations approved by the Council or so much thereof as may be required for the work of the Society shall be expended by the Secretary acting as Business Manager, under the direction of the various committees of the Society, and all bills against the Society for such expenditure shall be certified by the Secretary and shall then be sent to the Finance Committee for audit. Money shall not be paid out by any officer or employé of the Society except upon vouchers duly audited by the Finance Committee."

PROPOSED AMENDMENTS TO THE CONSTITUTION

AMENDMENT NO. 1

To add to the end of Section C 38 the following:

"The Council may also in its discretion appoint a person of the grade of Member to be an Honorary Secretary of the Society for a term not to exceed one year, but he may be re-appointed from year to year. He shall perform such duties as may be assigned to him by the Council which are in conformity with the Constitution and By-Laws, and with or without compensation as the Council may direct."

Mr. Charles Wallace Hunt in proposing the above amendment at the Chattanooga meeting said:

"It has been thought desirable that the Society should change one of the sections of its Constitution by putting in an additional clause whereby the Council should receive authority from the Constitution to appoint an Honorary Secretary. The proposition to create this office was referred to those members of the Society who as a Committee on Constitution and By-Laws prepared the present document under which the Society is at work, so that the wording of the proposed addition should be in accordance with the other parts of that instrument.

"I have in my hand the wording of an amendment to present under the provisions of Article C 57, which I present in writing for discussion and to come up for formal debate concerning its favorable consideration at the annual meeting in December.

"This proposed amendment is signed by myself and Messrs. Jesse M. Smith, D. S. Jacobus, George M. Basford, and R. H. Soule, who were the members of the original committee on Constitution and By-Laws."

AMENDMENT NO. 2

To add to Article C 45 after the words:

"House Committee" the words "Research Committee."

Mr. Jesse M. Smith in proposing the above amendment at the Chattanooga meeting said:

"I desire to offer an amendment to the Constitution looking towards the proposition to increase the scope and influence of the Society.

"It has been thought desirable that among the list of Standing Committees there should be one which in constitution and appointment would be similar to the other standing committees of the Society and which should be designated as the Research Committee.

"Such committee shall consist of five members, the term of one expiring at the end of each Society year, making the Committee as a body a permanent one, while changing in personnel from year to year. It is the purpose of the members presenting this proposed amendment to draft a set of By-Laws for the guidance of this Committee along the line of its work which will be presented to the Council for action and adoption under the constitutional provision made in Article C 59. There are many lines of engineering in which the Society ought to be able to take a significant part and at present the mechanism for doing work along the lines of research is practically lacking. This amendment is presented by Messrs. Jesse M. Smith, C. W. Hunt, G. M. Basford, D. S. Jacobus, and R. H. Soule, the same members who presented the previous proposed amendment."

Under C 57 of the Constitution the above amendments will be presented for discussion and final amendment at the December meeting. If 20 votes are cast in favor of submission to the entire voting membership of the Society this action will be taken. The final vote on an amendment to the Constitution is by sealed letter ballot, closing at 12 o'clock on the first Monday of March following the discussion.

VOLUME 27 NOW READY

The members are advised that shipments of Transactions, Vol. 27 (1906), will be made during November. A copy will be sent, all charges prepaid, to those members who have paid dues for the fiscal year 1905-06. The books will be distributed in all the large cities by the Western Union Telegraph Company, who so successfully handled the distribution of Vol. 26. It is believed this early publication of the Transactions will be appreciated by the membership. The Secretary should be advised at once as to any special instructions to be followed in making this delivery.

PROGRAM OF THE ANNUAL MEETING

The Annual Meeting will be held in the auditorium of the New York Edison Company, 44 West Twenty-seventh Street, whe.e the official headquarters will be opened Tuesday, December 4, at noon, and maintained throughout the meeting. Members and guests are requested to register as early as possible and to make this the opportunity to turn in their railroad certificates.

OPENING SESSION

Tuesday Evening, December 4, 8.45 o'clock

President's Address by Mr. Fred W. Taylor, Philadelphia, Pa., on "The Art of Cutting Metals."

SOCIAL REUNION

The reading of the President's Address will be followed by a social gathering, during which refreshments will be served. Ladies will be especially welcome at this session.

SECOND SESSION

Wednesday morning, December 5, at 9.30 o'clock

Annual business meeting. The annual reports of the Council, Tellers, Standing and Special Committees will be presented. New business can be presented at this session or at the Friday morning session.

Report of the Committee on Standard Proportions for Machine Screws.

Discussion on President's Address: "The Art of Cutting Metals."

In order not to curtail unduly the time to be devoted to the Social Reunion at the Opening Session, it has been decided to postpone the discussion of the President's Address until the Second Session, when ample time will be afforded for this purpose.

This session will adjourn punctually at 1 o'clock to the floor below, where buffet luncheon will be served.

THIRD SESSION

Wednesday afternoon, December 5, at 2 o'clock

POWER PLANT SYMPOSIUM

"The Evolution of Gas Power," by Mr. F. E. Junge, of Berlin, Germany.

"Producer Gas Power Plant," by Mr. J. R. Bibbins, of Pittsburg, Pa.

"Steam Turbine Characteristics," by Mr. Hans Holzwarth, of Hamilton, Ohio.

"A High Duty Air Compressor," by Prof. O. P. Hood, of Houghton, Mich.

"Design of an Improved Boiler Setting," by Mr. A. Bement, of Chicago, Ill.

"The Steam Plant of the White Motor Car," by Prof. R. C. Carpenter, of Ithaca, N. Y.

Wednesday evening unassigned

FOURTH SESSION

Thursday morning, December 6, at 10 o'clock

"Saw-Tooth Roof Construction," by Mr. F. S. Hinds, of Boston, Mass.

"Ferroinclave Roof Construction," by Mr. A. E. Brown, of Cleveland, O.

"Saw-Tooth Roofs for Factories," by Mr. K. C. Richmond, of Providence, R. I.

"Weights and Measures," by Mr. Henry R. Towne, of New York, N. Y.

EXCURSION

Thursday afternoon, December 6, at 2 o'clock

The excursion will be over the new electrically equipped lines of N. Y. C. & H. R. R. R. The start will be made from Grand Central Station.

RECEPTION

Thursday evening, December 6, at 9 o'clock

To be held at Sherry's, Forty-fourth Street and Fifth Avenue, entrance on Forty-fourth Street.

The President and President-elect will receive the members and guests. Dancing will follow the reception and will continue throughout the evening. Supper will be served from 10 until 12 o'clock. In order to avoid crowding, it is suggested that if those who must go out of town be served as soon after ten o'clock as possible and those who live in town delay their luncheon, all may be served with convenience. This is the only distinctively social feature of the meeting and the attendance of the visiting ladies is especially desired. It is urged that no one shall remain away because the exigencies of travel have made evening dress inconvenient. Cards of admission will

be required from all members and guests. These can be procured at the Registration Desk.

CLOSING SESSION

Friday morning, December 7, at 10 o'clock

"Mechanical Engineering Index," by Prof. W. W. Bird and Prof. A. L. Smith, Worcester, Mass.

"Ventilation of Boston Subway," by Mr. H. A. Carson, of Boston, Mass.

"Flow of Fluids in Venturi Tubes," by Mr. E. P. Coleman, of Buffalo, N. Y.

"Tests of an Elevator Plant," by Mr. A. J. Herschmann, of New York, N. Y.

"Test of a Rotary Pump," by Prof. W. B. Gregory, of New Orleans, La.

"Improved Transmission Dynamometer," by Mr. W. F. Durand, of Stanford University, Cal.

"A Plan to Provide Skilled Workmen," by Mr. M. W. Alexander, of Lynn, Mass.

RAILWAY TRANSPORTATION NOTICE

INSTRUCTIONS IN REGARD TO PURCHASE OF RAILWAY TICKETS FOR THOSE ATTENDING THE ANNUAL MEETING AT NEW YORK, DECEMBER 4–7

Certificate rates of a fare and a third for round trip have been secured for members and guests attending the Annual Meeting. A brief statement of the steps to be taken to secure this rate is given in heavy faced type. The balance of this announcement gives all the particulars.

a. Obtain a certificate when you purchase your ticket to New York.

b. Hand in this certificate with 25 cents when you register at Headquarters, or not later than December 7.

c. Call later at Registration Desk at Headquarters and get your certificate after it has been signed by Mr. Hoadley and the Railway Agent.

Arrangements have been made with the principal railway associations, by which those attending this meeting may secure the rate of one and one-third fare for the round trip, according to the "certificate plan." A person buying a ticket to New York, on November 30 to December 6 inclusive, and obtaining a certificate from the ticket agent at the time of purchase can secure at New York, up to December 11, a non-transferable return ticket for continuous trip over the same route for one-third the regular "limited" fare. This arrangement is subject to the important condition stated below, to which attention is specially called.

The concession of one-third fare for the return ticket is subject to the imperative condition that at least one hundred persons holding the certificates above described shall present the same to Mr. Francis W. Hoadley, Assistant to Secretary, Badge No. 4, with 25 cents for fee to Railroad Association, not later than December 7, and have them endorsed by him, to be subsequently endorsed by the agent of the railway associations at New York. It is necessary that we should have one hundred certificates in hand before the railway agent can endorse the first one. If that number is not actually produced, the whole arrangement becomes void, and even those who have certificates will be obliged to pay full fare in return. This is a matter over which we have no control, and can only state the case and ask the

hearty coöperation of members. Experience at past meetings has shown that members not caring to avail themselves of the "certificate plan" (because they wish to stay longer or to return by another route or to stop over by the way), often neglect to take certificates. Attention is therefore called to the following directions and requests.

Whether you mean to use the certificate or not, and if you buy a straight ticket, obtain a certificate from the ticket agent, naming the meeting of The American Society of Mechanical Engineers, as the purpose of the trip. Certificates are not kept at all stations. If, however, the ticket agent at a local station is not supplied with certificates and through tickets to place of meeting, he can inform you of the nearest important station where they can be obtained. In such a case you should purchase a local ticket to such station and there take up your certificate and through ticket to place of meeting. In many cases an agent at a station of minor importance will, upon request, secure the certificate or the through ticket, or both, when sufficient time is afforded him to do so. It costs nothing to secure certificates and by doing it you may render an important service to fellow-members. It is especially urged that everyone secure a certificate of the purchase of his going ticket, even if not intending to avail himself of reduced rate on the return. By handing the certificate to Mr. Hoadley or one of his assistants at the Registration Desk, it will help to secure the concession for others. No refund of fare can be made on account of any person failing to secure a certificate.

At the close of this announcement will be found a list of the associations from whom we have heard up to the present time concerning this rate.

To prevent all misunderstanding, call beforehand on the ticket agent of whom you mean to purchase your ticket, and find out whether his office has the appropriate blanks and instructions. In case of difficulty, write at once to the undersigned; and that you may have time to do this, make your preliminary inquiry in ample season.

No special delegates' tickets or certificates can be transferred to scalpers or brokers. The Society has to redeem at full fare any tickets which are so detected.

No certificate can be signed by Mr. Hoadley or the railway agent after December 7, therefore turn them in promptly when you register on arrival at Headquarte s. We must get one hundred together before any can be endorsed by the railway agent. Delay in presenting your certificate may seriously affect others.

Arrangements for transportation, as explained above, hotel accommodation, etc., should be made personally by each member attending the meeting.

Up to the time of going to press the following railroad associations have advised us that the certificate rate has been granted:

Trunk Line Association, covering the following territory:

Niagara Falls, Buffalo, Dunkirk, and Salamanca, N. Y., Erie and Pittsburg, Pa., Bellaire, O., Wheeling, Parkersburg and Huntington, W. Va., and points east thereof, except in New England, comprising the following lines:

Baltimore & Ohio (Parkersburg, Bellaire and Wheeling, and east thereof),
Buffalo & Susquehanna,
Buffalo, Rochester & Pittsburg,
Central of New Jersey,
Chesapeake & Ohio (Huntington, W. Va., and east thereof),
Chesapeake Steamship Co.,
Cumberland Valley,
Delaware & Hudson,
Delaware, Lackawanna & Western,
Erie (Buffalo, Suspension Bridge, Dunkirk, Salamanca and east thereof),
Fonda, Johnstown & Gloversville,
Jamestown, Chautauqua & Lake Erie,
Lehigh Valley,
New York Central & Hudson River, Main Line and Branches, including R. W. & O., Adirondack and Penna. Divisions, but not including stations on the Harlem and Putnam Divisions.
New York, Ontario & Western,
New York, Phila. & Norfolk,
Norfolk & Washington Steamboat Co.,
Pennsylvania, including Buffalo & Allegheny Valley Division (formerly W. N. Y. & P. and Allegheny Valley Railways),
Northern Central,
Philadelphia & Erie,
Philadelphia, Baltimore & Washington,
Washington Southern,
West Jersey & Seashore,
Philadelphia & Reading,
Pittsburg, Shawmut & Northern,
Washington Southern,
Western Maryland,
West Shore.

Central Passenger Association, covering the following territory:

Bounded on the East by Pittsburg, Salamanca, Buffalo and Toronto; on the North the line of, and including points on the Grand Trunk Railway, from Toronto to Port Huron, thence via Lakes Huron and Michigan to Chicago; on the West by Peoria and Keokuk, Quincy, Hannibal, St. Louis and Cairo; and on the South by the Ohio River, but including points on either side of that river:

Ann Arbor R. R.,
B. & O. R. R.,
B. & O. S. W. R. R.,
B. & L. E. R. R.,
Big Four Route,
C. & O. Ry,
Chicago & Alton R. R.,
C. & E. I. R. R.,
C. & E. and Erie R. R.,
C. I. & E. R'y,
C. I. & L. R'y,
C. I. & S. R. R.,
C. R. I. & P. R'y (between Chicago and Peoria, via Bureau),
C. & M. V. R. R.,
C. H. & D. R'y,
C. N. O. & T. P. R'y,
Cin. Northern R. R.,
C. A. & C. R'y,
C. & B. Transit Co.,
C. C. & L. R. R.,
Dayton & Union R. R.,
D. & B. S. Co.,
D. & C. N. Co.,
D. T. & I. R'y,
D. T. & M. R. R.,
D. A. V. & P. R. R.,
E. & I. R. R.,
E. & T. H. R. R.,
G. R. & I. R'y,
G. T. R'y System,
Hocking Valley R'y,

Illinois Central R. R.,
L. E. A. & W. R. R.,
L. E. & W. R. R.,
L. S & M. S. R'y,
L. & N. R. R.,
L. H. & St. L. R'y,
M. C. & C. R.R.,
Mich. Central R. R.,
Mobile & Ohio R. R.,
N. Y. C. & St. L. R. R.,
N. & W. R'y,
Ohio Central Lines,
Penna. Lines,
Pere Marquette R. R.,
P. & L. E. R. R.,
P. L. & W. R. R.,
So. R'y (St. Louis Div.),
T. P. & W. R'y,
T. St. L. & W. R. R.,
Vandalia Railroad,
Wabash R. R.,
Wab. Pitts. Ter. R'y,
W. & L. E. R. R.,
Z. & W. R'y,

New England Passenger Association, covering the New England States, and embracing the following roads:

Bangor & Aroostook R. R.,
Boston & Albany R. R.,
Boston & Maine R. R.,
Canadian Pacific R'y,
Central Vermont R'y,
Eastern Steamship Co.,
Grand Trunk R'y,
Maine Central R. R.,
New York, New Haven & Hartford R. R.,
Portland & Rumford Falls R'y,
Rutland R. R.,
Quebec R. R.

Southeastern Passenger Association, from all points in territory south of the Ohio and Potomac and east of the Mississippi rivers, and embracing the following roads:

Alabama Great Southern Railroad,
Alabama & Vicksburg Railway,
Atlantic Coast Line Railroad,
Atlantic & North Carolina Company,
Atlanta, Birmingham & Atlantic Railroad,
Baltimore & Ohio Southwestern Railroad,
Blue Ridge Railway,
Central of Georgia Railway,
Charleston & Western Carolina Railway,
Cincinnati, New Orleans & Texas Pacific Railway,
Florida East Coast Railway,
Georgia Railroad,
Georgia, Florida & Alabama Railway,
Georgia Southern & Florida Railway,
Gulf & Ship Island Railroad,
Illinois Central Railroad,
Louisville & Nashville Railroad,
Macon & Birmingham Railway,
Macon, Dublin & Savanna Railroad,
Mobile & Ohio Railroad,
Nashville, Chattanooga & St. Louis Railway,
New Orleans & Northeastern Railroad,
Norfolk & Southern Railroad,
Norfolk & Western Railway,
Richmond, Fredericksburg & Potomac Railroad,
St. Louis & San Francisco Railroad,
Seaboard Air Line Railway,
Southern Railway,
Virginia & Carolina Coast Railroad,
Washington Southern Railway,
Western & Atlantic Railroad,
West Point Route (A. & W. P. R. R. and W. Ry. of Ala.),
Wrightsville & Tennille Railroad,
Yazoo & Mississippi Valley Railroad.

In case any railroad which you want to use is not included on this list advise the Secretary promptly.

BENJAMIN HOWARD WARREN

Benjamin Howard Warren, a member of the Society since its organization in 1880, and a Vice-President from 1898 to 1900, died in New York, October 20, of cerebral apoplexy. He was born in Dorchester, Mass., February 19, 1850, being the elder son of the late Captain Moses H. Warren, who commanded Company I of the First Massachussetts Volunteers at Spottsylvania, where he was killed May 12, 1864. His mother was Ann M. (Longley) Warren of Boston, who died November 13, 1905.

Mr. Warren was graduated from the United States Naval Academy in 1874, in the class of engineers, and was placed on the retired list June 11, 1878, on account of partial deafness. He then entered the employ of the Hancock Inspirator Company, and about four years later took charge of their works. From 1890 to 1895, he was manager of the crane department of the Yale & Towne Mfg. Co., Stamford, Conn., and was later Secretary and Treasurer of the Pratt & Whitney Company, Hartford, Conn. In 1896 he entered the service of the Westinghouse Electric and Manufacturing Company, Pittsburg, Pa. as assistant general manager and was shortly afterwards made vice-president. In 1904, he became president of the Allis-Chalmers Company, bringing under one executive head the various companies and allied interests controlled by it. In January, 1906, he formed a partnership with two of his old friends, John C. Kafer and Asa M. Mattice, as consulting engineers, under the firm name of Kafer, Mattice & Warren. Mr. Kafer died soon after the forming of the partnership.

Mr. Warren was a member of the Society of Naval Architects and Marine Engineers, the American Society of Naval Engineers, the Loyal Legion, the Engineers' Club, the University Club of New York and the Lawyers' Club.

For a number of years past his home has been in Alberene, Virginia, where he had a large estate. He leaves a widow, formerly Miss Elizabeth R. Mitchell of Quincy, Mass., two daughters, and a son, a recent graduate of Harvard. He is survived also by his brothers, Arthur Warren, of the editorial staff of the "Boston Herald," and by his sister, Mrs. Thomas E. Ewing of Dorchester, Mass.

Funeral services were held at the Church of the Incarnation, New York, and the remains were then taken to Quincy, Mass., and interred in Mount Wollaston Cemetery.

LETTER FROM PRESIDENT TAYLOR

Draft of Circular Letter Sent to Members of the Society Accompanying the Ballot for Officers

Since some reference has been made in the technical journals to the fact that the Council of The American Society of Mechanical Engineers had received a letter of request from its present Secretary that he might be relieved of the duties of Secretary at the end of the current Society year, it seems fitting that an official communication to the members of the Society should be made concerning this matter. The issue from the Society's office of the ballot for officers for the ensuing year makes it appropriate that this notice should be given at this time.

At a meeting of the Council, held January 30, 1906, the following letter was presented by the Secretary:

New York, January 29, 1906.

To the Council, The American Society of Mechanical Engineers.

Gentlemen:

It may be known to some members of the Council that for several years I have had the thought in mind of resigning the Secretaryship of the Society on the completion of 25 years of service. I was first elected in March, 1883. My more recent thought has been that instead of waiting for a mere sentimental period to elapse, which would have meaning to myself alone, I might rather emphasize the more obvious culmination of my service to the Society by withdrawing at the time when the Society shall cross the threshold of its new home in the Engineering Building. It will then have been given to me to have wrought for the Society from the days of small beginnings, when I paid my own office rent and expenses, through the period of rented offices and of the ownership of the modest home in Thirty-first Street, and up to the opening of the days of larger opportunity in the splendid surroundings of the new enterprise.

It is wise, I am sure, that at the time of this external change, the Society should also make the internal change incident to securing as its Secretary one who will and can devote his entire time to the work and development of the Society.

It is well known to you that I have felt that I owe and must pay my first allegiance to the work of my professorship in Columbia University.

This being the case the Council should be advised far enough in advance so that the least embarrassment may be entailed by my withdrawal. I have thought it best to present this formal letter at the first meeting of the year, and to ask by it that proper action may be taken looking to the questions for the future which it raises. I ask that I may be relieved of the duties of the Secretaryship at the end of the current Society year, or at such other time thereafter as the Council may see fit to have this resignation take effect.

[Signed] F. R. Hutton, *Secretary.*

The Council was a unit in emphatic expressions of regret that this step should have seemed necessary to the Secretary, and used all appropriate means to influence him to reconsider or postpone the action. On finding that this was impossible, a committee was at once appointed to consider the selection and nomination of a suitable person to succeed the Secretary when his term of office should expire, so that the Society should not suffer from a change in its Secretary. This Committee was very fortunate in being able to decide upon a nominee so placed as to be able to come into the Society's office without waiting for the end of the year, and begin his effective service in advance of the beginning of the Society's year. The choice fell upon Mr. Calvin W. Rice, who became assistant to the present Secretary, giving his entire time to the duties of the Society's office, with the understanding that when the term of the present Secretary should expire he would accept the election as his successor. Mr. Rice, therefore, technically holds the position of Assistant to the Secretary until the end of the current year.

Meantime, earnest consideration was given by the Council to find a fitting way in which the Society might recognize the services which had been rendered by the retiring Secretary, and which could in no way be considered as having been compensated for by the emoluments of his office. The Nominating Committee also sought advice and suggestions for the conduct of its work.

The outcome of both sets of inquiries was the proposition that the retiring Secretary should be made President of the Society for the coming year and his name will be found upon the official Officers' Ballot enclosed you herewith.

This policy has commended itself not only in the special conditions now prevailing, but as one which would be appropriate in the future history of the Society where effective service in a lower office should be recognized by nomination to a higher.

The Council trusts that the action of the Nominating Committee, taken with the full concurrence of the Council, will commend itself to the membership.

Respectfully,

FRED W. TAYLOR,

President.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both as to positions and as to men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 20th of the month. The list of men available is made up entirely of members of the Society and these are on file, with the names of other good men, not members of the Society, capable of filling responsible positions, information about whom will be sent upon application.

POSITIONS AVAILABLE

01 Wanted by an engine building concern, in Ohio, a man competent to take charge of the shops, as Superintendent of Construction. Must be familiar with the manufacture of steam and gas engines.

MEN AVAILABLE

1 Associate member, mechanical engineer and designer, 35 years of age, practical and technical. Extended experience in design and construction of machinery and mechanical appliances, mill factory construction and equipment. Thoroughly up-to-date machine tool designer, jigs, fixtures, punches and dies, limit gages. Special and automatic machinery for the production of fine and medium heavy interchangeable work. Excellent executive ability and can produce results. Desires position where services will be appreciated. Best references from past and present employers.

2 Mechanical Engineer, technical graduate, experienced as superintendent and works manager on general work, largely in the manufacture of pumps. Well versed in first-class brass and iron foundry and machine shop practice. An organizer and executive; costs reduced and production increased. Successful in handling workmen. Now employed, can arrange to change on two to three months' notice.

3 Executive position desired in manufacturing establishment. American, age 37, fourteen years' experience, in shop, as foreman. Drawing-room seven years in addition to executive experience. Technical education, Cornell University.

4 Technical graduate desires to change position, fourteen years' practical shop and drawing-room experience, having held positions with large and modern concerns, as mechanical draftsman, designer, chief draftsman, assistant to Superintendent. Commercial Engineering experience four years, as representative and salesman. Thor-

oughly acquainted with the machinery trade in New England and New York States. Would consider a position with a concern desiring a man to act as representative and mechanical engineer, either on salary or commission basis. Machine tools, special and general machinery. Excellent reference as to ability and character. Location, New York and vicinity preferred.

5 Junior member, technical graduate. Six years' experience steam engineering. Drafting, installing, and testing engines, boilers, and pumps; familiar with A. S. M. E. Code for conducting engine and boiler tests, fuel and flue-gas analyses. Desires a position with firm engaged in general steam engineering work or as consulting engineer for steam power installations.

6 Junior member, mechanical engineer. Desires position as assistant or to take charge of practical shop work. Good theoretical knowledge and practical experience. Familiar with the different branches of mechanical engineering, and the erection of Corliss engines, condensers, heaters, pumps, etc. Exclusive position as draftsman, except in connection with practical work not desired, satisfactory reference.

7 Mechanical Engineer (married), now in charge of important engineering and business interests for foreign corporation, desires responsible connection with American concern. Special training, commercial and engineering experience for manufacturing and operating work.

8 Shipyard manager or Supterintendent. Experienced in all departments of shipyard and dry-dock work. Designer of engines, boilers and hulls, and estimater on both new and repair work. Technical graduate and familiar with shipyard and repair plants on Atlantic Coast.

9 Junior, Michigan graduate. Six years' experience, chief draftsman with large manufacturing company. Desires position with commerical vehicle or gasolene engine as mechanical engineer, assistant to manager or assistant superintendent. Three years' exclusive experience on delivery wagons, trucks up to six tons, sight-seeing cars, gasolene railroad cars, up to 30 passengers, gasolene locomotives. Can handle office, drafting-room, orders, or correspondence.

10 Massachusetts Institute Technology graduate. Varied experience in mechanical and electrical work, including positions as superintendent of electric lighting company and manager of district office of manufacturing company. Position desired as manager or engineer in manufacturing or construction, preferably in the development of new industry.

11 Wanted a position as manager, or general superintendent, or would prefer to take position as engineer to some good reputable firm. Technical graduate. Twelve years' experience in the shop.

12 A member of large experience in the design and construction of machinery, desires position as head draftsman or mechanical engineer with a manufacturing concern.

13 Technical graduate, eleven years' experience, will take management or assistant of small manufacturing establishment on salary or percentage basis.

14 Mechanical engineer, thoroughly posted in steam turbine designs, is open for a position as designer, assistant engineer or assistant superintendent. Six years' drafting and designing experience, with own ideas. Age 28, single, references.

15 Member, with broad practical experience in industrial installations, manufacturing and business management. Familiar with foundry work (loam and sand), also general shop practice. Safe estimater. Has held position as superintendent of construction, shop manager, sales. Open for engagement as representative for New York or Eastern States. Would consider a position as construction or maintenance engineer. Eighteen years' experience.

16 Technical graduate, 31 years of age. Experience in office, drawing-room, field, power plant and mill construction. Some machine shop experience. Desires a change.

17 Wanted a position as master mechanic of a railroad by a graduate in mechanical engineering with five years' experience as machinist, five years as foreman and eight years as master mechanic.

18 Massachusetts Institute of Technology, '94, post-graduate course in electrical engineering. General experience in design and in charge of product of company engaged in manufacture of steam and electric hoists, derricks of steel and wood, and locomotive cranes up to capacity of 40 tons. In government work conducted physical tests upon materials used, including two large steel frame shop buildings, as well as smaller brick, stone and wooden buildings. Extended experience with company manufacturing electrically operated watertight bulkhead doors for ships, installed apparatus on 32 of largest ships of the U. S. Navy. Desires work of general engineering character.

19 Merchant engineer and factor will open office in London, and introduce in Great Britain, Germany, Belgium, France and Austria, the special product of American firms, dispose of their foreign patents and organize subsidiary companies. Will also act as investigator and purchasing agent for individuals and firms desiring information regarding special processes, equipment and materials best obtainable in any of the above countries. Member.

CANDIDATES FOR MEMBERSHIP

Record of Qualifications, Engineering Experience and References

This list should be treated as *confidential* and be subject to inspection by members of the Society only. The names are those of candidates whose applications have been approved by the Council and the Membership Committee. The names appear in the same order as they do on the ballot sent to the voting membership under date November 1, 1906.

TO BE VOTED FOR AS MEMBERS

EDWIN HUGH AHARA

EDWIN HUGH AHARA, Supt. Dodge Mfg. Co., Mishawaka, Ind. Born Evansville, Wisconsin, 1865. Evansville Seminary, B.C.E.; M.E., University of Wisconsin, 1892-1896. Shop experience, Eclipse Mfg. Co. (Beloit, Wis.), 1887-1890, general machine shop work, also Esterly Harvester Co. (Whitewater, Wis.), and Superintendent at Minneapolis Shops from 1893-1894. Transit operator, U. S. Government on upper Mississippi for short time. Deering Harvester Co. (Chicago), 1895-1902, in charge of tool and mechanical equipment. Manager manufacturing department, Dodge Mfg. Co. (Mishawaka, Ind.), 1902. Present position, General Superintendent, Dodge Mfg. Co.

References: Melville W. Mix, J. H. Pitkin, E. C. DeWolf, Storm Bull, D. C. Jackson.

FRANK CONANT ARMSTEAD

FRANK CONANT ARMSTEAD, care of Westinghouse Machine Company, E. Pittsburg, Pa. Born Cleveland, Ohio, 1862. Apprentice as machinist, Variety Iron Works (Cleveland), 1881-1885. Shop experience Eberhard Mfg. Co. (Cleveland), 1885-1886. Other practical experience with Chicago City Railway Co. 1886-1887. Operating engineer Westinghouse, Church, Kerr & Co.; erecting engineer from 1887 to 1904, during which time employed on general construction work, erecting steam and gas engines, stokers and other machinery; also in charge of installing complete power plants which include Columbus Central Railway (Columbus, O.), Cincinnati, Newport & Covington Ry. Co. (Newport, Ky.), Detroit, Ypsilanti & Ann Arbor Ry. Co. two plants, one at Ypsilanti and one at Dearborn (Mich.). January, 1898, assigned to New York Office of Westinghouse, Church, Kerr & Co. as superintendent of construction in charge of boiler room equipments. Since 1904 Supervising Engineer with Westinghouse Machine Company in Stoker Department in general charge of design and installation stoker equipments.

References: Walter C. Kerr, E. E. Keller, W. W. Churchill, Geo. B. Caldwell, Jay M. Whitham.

GUSTAV AYRES

GUSTAV AYRES, 705 McGill Bldg., Washington, D. C. Born Elizabeth, N. J., 1866. M. E., Lehigh University, 1889. Apprentice machinist trade Union Pacific R. R. (Omaha), 1889-1891. Practical experience on tests and reports on power plants, pumping stations, explosive engines, oil burners, etc., from 1892-1906, Asst. Examiner U. S. Patent Office, 1892-1897; Professor of Mechanical Engineering at Columbian University (Washington, D. C.), 1898-1901. Installed mechanical engineering laboratory at Columbian University. Cons. Engr. and patent expert tests and reports of power plants and varied commercial factories, 1898-1906. Inspection and report on 1400 H. P. suction dredge for Hughes Bros. & Bangs of N. Y. City, 1900. Tests and designing for American Turbine Engine Co., 1903-1906. Present position Patent Expert and Consulting Engineer in own business.

References: J. F. Klein, A. Johnston, G. L. Morton, H. Hollerith, H. S. Knight.

GEORGE OTIS BAKER

GEORGE OTIS BAKER, 135 West 116th St., N. Y. City. Born Warren Ill., 1860 Four years State Normal School (Muncy, Pa.). Apprentice, DeHass Bros. Carriage Machine Works, 1876-1880. Drawing-room, United Edison Mfg. Co. power house plans, and later General Electric Co., 1889-1900 inclusive. 1880-1884, erecting engineer for Central Pa. Telephone Co. (Williamsport, Pa.) 1884-1889, Superintendent Bellefonte Edison Co. (Bellefonte, Pa.). 1889-1900, erecting engineer for United Edison Mfg. Co., later General Electric Co., in connection with drafting room, as previously noted, designing power and lighting plants. 1901 to date, Mechanical Engineer for New England Engineering Co., designing and building lighting, railway and power plants.

References: A. J. Purinton, F. A. Larkin, Thos. M. Eynon, F. E. Idell, W. L. R. Emmett.

JAMES DOUGHTY BECK

JAMES DOUGHTY BECK, 2331 Constance St., New Orleans, La. Born New Orleans, La., 1862. Technical education, Mechanical and Agricultural College, night classes at New Orleans, La., now at Baton Rouge, La. Apprentice, A. E. Scheidecker as machinist, 1876-1881, on printing press work, tobacco machines, marine work and general machinery. Drawing-room work on Patent Office sheets and other drawings at night, 1884-1885; Cochran & Mims Marine Works (New Orleans), 1885, 1886 and 1889. A. E. Dupas, M.E. (New Orleans), 1887. General drawing-office, 1895-1896; Louisiana Electric Lt. and Power Co., 1896-1897 Schwartz Foundry Co. Shop experience, Cochran & Mims Marine Works, 1882-1889; Leeds & Co., sugar machinery, 1887, and Shakespeare & Swoop; Buchel Machine Works, models for electricians, 1890-1891; New Orleans Swampland Reclamation Co., 1901-1904. 1886, designed the Loque Patent high speed counterbalanced reciprocating engine at New Orleans, La. 1889-1890, superintended construction of the steel stein wheel at Kissimmee, Fla., and erecting compress machinery for Cochran & Mims (New Orleans, La.); 1891-1894, superintendent and mechanical engineer for the New Orleans Swampland Reclamation Co., in charge of machine shops and all other departments. 1895, designed and made complete set of detail drawings for a 48″ centrifugal pumping plant with special engines for the New Orleans Swampland Rec. Co. (New Orleans, La.). 1896-1897, in charge of the

drawing-office and construction for the Louisiana Electric Light and Power Co. of New Orleans. 1897-1903, general foreman in charge of all departments for the Schwartz Fdy. Co., Ltd. 1903 to date, Superintendent in charge of all designing and construction, Schwartz Foundry Company.

References: E. A. Sammons, R. T. Burwell, S. E. Freeman, W. B. Gregory, H. T. Rugan.

WILLIAM RICHARDSON BILLINGS

William Richardson Billings, Alberger Condenser Company, 95 Liberty St., N. Y. City. Born Brooklyn, N. Y., 1853. B. S., Worcester Polytechnic Institute, 1871. Shop training at Washburn Shops in Worcester, Mason Machine Works in Taunton and others for short terms, 1871-1879. Drawing-room, Mason Machine Works (Taunton), 1872-1876. Three years of school teaching, surveying and drawing. From 1879-1888 superintendent, clerk and engineer of the Taunton Water-drawing Department. Laid out water mains, built water supply conduit, filter bed, river bank wall and sundry small matters. Salesman for Chapman Valve Mfg. Co. (Indian Orchard, Mass.), 1888. Treasurer and general manager Taunton Locomotive Mfg. Co. (Taunton, Mass.), 1888-1905. Developed and improved the Wainwright feed water heater and also expansion joints. Present position, manager Wainwright Department, Alberger Condenser Company.

References: Geo. F. Swain, Milton P. Higgins, Francis W. Dean, Louis R. Alberger, John T. Hawkins.

JOHN QUINCY BROWN

John Quincy Brown, Oakland Traction Cons. & S. F., Oakland & San Josè Ry., Oakland, Cal. Born Ironton, Ohio, 1875. Common schools and 1 year Ohio State University; M. E., Ohio State University, 1898. Apprentice, Shop of Columbus Ry. Co. part of 1895–1896, erecting work, machines and electrical shops. Drawing-room, Columbus Ry. Co., 1897. designing cars, wiring, switchboards and general work, also special work. Secretary and acting manager, Columbus Electric Co., 1898–1899, designed and erected 930 H. P. gas engine, 2-phase lighting plant, including building and distribution. Special work in photometry of arc lamps as member of Committee for National Electric Light Association. General manager in charge of all departments San Antonio Traction Co., 1899–1900. Oakland Traction Cons. 1900 to date, direct supervision of all engineering work. Same for San Francisco, Oakland & San José Ry., designed all rolling stock, shops and power stations complete. Designed and patented special trolley for heavy multiple unit trains; designed new type of truck, also much special and original work. Present position, assistant general manager and engineer two roads, Oakland Traction Cons. and San Francisco, Oakland and San José Railway, supervising all engineering work and general business.

References: John H. Hopps, Stillman W. Robinson, Wm. T. Magruder, H. L. Doherty, E. A. Hitchcock.

JOHN FRANCIS BUCKLEY

John Francis Buckley, 4 Cottage Lawn, Beloit, Wis. Born Sterling, Ill., 1866. Graduated Illinois High School; Four years' study mechanical design during apprenticeship, at Taft Bros. Sterling, Ill.), Oct., 1883-1887; drawing-room, same company. Shop experi nce, Charter Eng. Works (Sterling, Ill.), experimental work, Dec., 1887-1893; coast gun erector, R. I. Arsenal (Ill.); tool maker

U. S. Steel Lock Co. (Clinton, Ia.); tool maker, Columbian Stamping Co. (Terre Haute, Ind.); special machine builder, Geo. W. Whitcomb Co.; 1897 to present time, in charge of plants manufacturing several lines of machinery. With E. Bauder (Sterling, Ill.), foreman of special machinery model and pattern making, 1897-1899; Supt. Sterling Machine Works, builders of special machinery, 1899-1901; Supt. Wolley Foundry & Machine Works (Anderson, Ind.), gas engine builders, 1901-1903. Present position, Supt., J. Thompson & Sons' Gas Engine Works (Beloit).

References: James A. Charter, W. F. Barnes, J. Wendell Cole, Alfred Marshall, Jno. D. Bird.

S. A. BULLOCK

S. A. Bullock, 17th Street Shops, Baldwin Locomotive Works, Phila. Born Lexington, Kentucky, 1876. B. M. E., Kentucky State College, 1897; M. E., 1904. Apprentice, L. & N. R. R. repair shops with Mr. P. Leeds, Jan., 1899, to June, 1900; machine work and erecting locomotives. Drawing-room, designer of locomotives and shop equipment under Mr. Max Toltz, G. N. R. R. (St. Paul), July, 1902, to Dec., 1902. Designer and chief draughtsman, A. C. & F. Co. (New York, and Berwick, Pa.) Dec., 1904, to June, 1906, under A. E. Ostrander, N. Y. and H. P. Field, Berwick, Pa. Master Mechanic, L. & A. R. R. (Richmond, Ky.) Jan., 1901, to June, 1902. Chief draughtsman, A. C. & F. Co. (Berwick, Pa.) April, 1905, to June, 1906, in charge of the design of wooden and steel freight cars. Present position, Inspector Baldwin Locomotive Works, in charge of the inspection of electric locomotives and tenders and the output of the 17th Street Shops.

References: S. M. Vauclain, H. F. Glenn, Wm. H. Collier, J. T. Faig, Geo. Gibbs.

CHARLES J. CALEY

Charles J. Caley, Russell & Erwin Mfg. Co., New Britain, Conn. Born Jersey City, N. J., 1863. Yale & Towne Mfg. Co., 1891–1898 (Stamford, Conn.); Sargent & Co. (New Haven, Conn.) 1898–1901 and 1887–1890. General Superintendent Russell & Erwin Mfg. Co. (New Britain, Conn.), superintended the building and equipping of their new building. Granted twenty-one U. S. Patents, improvements in hardware.

References: Chas. M. Jarvis, H. S. Hart, A. W. Stanley, E. H. Mumford, H. K. Jones.

HENRY MAYO CHASE

Henry Mayo Chase, Deane Steam Pump Co., 199 Walnut St., Holyoke, Mass. Born Holyoke, Mass., 1869. Four years Holyoke High School; 3 years Mass. Institute Technology. 1892-1897, Designer Deane Steam Pump Co. (Holyoke). 1897-1898, Atlantic Refd. Machine Co. (Springfield, Mass.). 1898-1899, Engineer De La Vergne Ref'g Machine Co. (New York). 1900-1901, Designer Deane Steam Pump Co. (Holyoke); 1891-1892, laying out work in machine shop, Deane Steam Pump Co. 1901-1904, in charge of engineering department, Deane Steam Pump Co. 1904-1906, Chief Draftsman, having charge of engineering and design, Deane Steam Pump Co. Present position, Chief Draftsman, same company.

References: C. L. Newcomb, C. L. Griffin, S. M. Green, C. H. Jenness, F. N. Fowler.

JOHN HENRY CLARK

JOHN HENRY CLARK, Cons. Engr. General Electric Co., Schenectady, N. Y. Born Cornwall, England, 1859. Apprentice, Cook, Rymes & Co. (Charlestown, Mass.), 1875-1878; Drawing-room, Cook, Rymes & Co., B. F. Sturtevant, and Whittier Machine Co., and with Governor Oliver Ames, 1881-1892; shop experience, Whittier Machine Co. and Brayton Petroleum Engine Co., 1875-1892. With Thomson-Houston Electric Co. and General Electric Co., 1892 to date, designing, constructing and superintending manufacture of all classes of machinery. Present position, Consulting Engineer, General Electric Company.

References: A. L. Rohrer, John Riddell, Louis R. Alberger, Chas. R. Pratt, Wm. Schwanhausser.

WILLIAM VALDEMAR DAM

WILLIAM VALDEMAR DAM. Parker St., Castlemaine, Victoria, Australia. Born Auckland, New Zealand, 1864. Attended private and state schools and private and Working Men's College at Melbourne. Apprentice, Bay of Islands Coal Co. (Auckland), making and repairing mining plant and locomotives, 1881-1885; worked as journeyman for same company, 15 mos. Drawing-room the Austral-Otis Eng'g Co. (So. Melbourne), general engineers, Sept., 1893-Nov., 1895, principally on mining machinery. Shop experience, Bay and Island Coal Co. and Austral-Otis Co., 1881-1887, and 1897-1899. Three years erecting all classes of hydraulic elevators and machinery appertaining thereto. Foreman of machinists and erectors at Austral-Otis Works for 2 years; designed and superintended erection of hydraulic machinery for same company, also inspector of elevators for 2 years in Melbourne, Sydney, Adelaide and Brisbane. Sept., 1891, placed on official staff of the Austral-Otis Eng'g Co., occupying a leading position with them till July, 1900, including estimating, technical correspondence and writing of new specifications for 18 months, also in charge of an ore treating works for same period, treating various kinds of ore mechanically and chemically and experimenting with new mining machinery. Asst. Mgr. for the Austral-Otis Co., Nov., 1899-July, 1900. Joined Thompson & Co., general engineers (Victoria, Australia), July, 1900. Works Manager; now Asst. General Manager and Engineer for Thompson & Co., engaged in design and manufacture of general machinery, high class mill engines, pumping machinery, boilers, air compressors, etc.

References: (Applies under B-2 of the By-Laws.)

EDWARD P. DECKER

EDWARD P. DECKER, 10 Bridge Street, New York City. Born Evansville, Ind., 1870. Public Schools and 3½ years Rose Polytechnic Institute. Apprentice, Thomson-Houston Electric Works on electric machinery, 1889. Drawing-room, Thomson-Houston Electric Co. (Lynn, Mass.). Evansville Street Railway Co., N. Y. Telephone Co., J. G. White & Co., Westinghouse, Church, Kerr & Co. (New York). Sprague Electric Elevator Co. (Watsessing, N. Y.), assistant to factory manager. 1892, superintendent of outside construction, Evansville Street Railway, designed power and building equipment for Broad, 18th and Franklin Exchanges; mechanical equipments for Telephone Building (New York), also interior block system of cable distribution for New York Tel. Co., 1892-1897; designed and constructed Municipal Lighting Plant (Owrensboro, Ky.), 1899. Engineer in charge mechanical and electrical equipment, L. & W. V. R. R. in Penna., 1900-1904,

also mechanical and electrical equipment N. Y. N. H. & H. R.R.R., Fall River Division, 1904-1905. Present position, engineer with Westinghouse, Church, Kerr & Co., engaged in construction of 14 story fire-proof hotel building in Detroit.

References: Walter C. Kerr, W. W. Churchill, H. R. Kent, S. D. Collett, G. B. Caldwell.

WILLIAM NOBLE DICKINSON, Jr.

William Noble Dickinson, Jr., Otis Elevator Co., 17 Battery Place, New York City. Born New York City, N. Y., 1872. Two years Pratt Institute; one year Polytechnic Institute of Brooklyn and private tutor. Separate evening course in drawing at High School (Springfield, Mass.), during one winter. Also drafting with Elektron Mfg. Co. Two years machine shop Pratt Institute, 1888-1889; electric shop with Elektron Mfg. Co., on bench and as foreman of winding room, 1889, 1891, 1892. In charge of testing room for Elektron Mfg. Co. Supervision of installation small lighting plants and electric elevators for Elektron Mfg. Co., including erection of elevator exhibit at World's Fair (Chicago), 1893. General supervision of eastern New England work while in charge of Boston office. Design and installation of elevator work under firm name of W. Noble Dickinson, Jr., and W. Noble Dickinson, Jr. & Co. (New York City), during years, 1900-1901. Superintendent at Otis Elevator Co., Chicago works, during absence of superintendent and technical correspondence at same plant. In charge of engineering work Otis Elevator Co.'s Pacific Coast Department (San Francisco). Present position, special work at Otis Elevator Co., in connection with alternating current elevators.

References: Geo. B. Caldwell, W. J. Baldwin, S. D. Collett, Chas. R. Pratt, F. E. Town.

FRANK DOBSON

Frank Dobson, 319 East 53d Street, New York City. Born New York City, 1861. Apprentice, Baker Smith & Co., and Bonner & Van Court, steam heating and ventilating, 1876-1886. Drawing-room, as above and in own establishment. Apparatus for heating and ventilating, Asylum for Insane, Central Islyp, N. Y., at Wards Island, N. Y. and Bellevue Hospital, several public schools in New York. At present, constructing the ventilating and heating plant in N.Y. Public Library.

Rererences: J. Leland Wells, Wm. H. McKiever, J. A. Almirall, J. M. Robinson, F. A. Scheffler.

LOUIS CHARLES DOELLING.

Louis Charles Doelling, DeLaVergne Machine Co., foot E. 138th St., New York City. Born Germany, 1871. Twelve years college at Karlsruhe; 4½ years at Hanover and Charlottenburg technical schools. 1889-1890, apprentice, Rowling Bros., Hanover, in foundry and machine shops. One and one-half years draftsman with T. A. Maffie (locomotive builders), Munich; 2 years with Rowling Bros., Hanover; 2 years salesman at Karlsruhe; 2 years testing engineer at Hanover and manager in the Vienna works. Present position, Vice-President and General Superintendent DeLaVergne Machine Co.

References: A. K. Fischer, C. W. Whiting, H. H. Morrison, C. E. Lucke, James M. Cremer, F. R. Hutton.

THOMAS COLEMAN DUPONT

THOMAS COLEMAN DUPONT, President E. I. DuPont de Nemours Powder Co., Wilmington, Delaware. Born Louisville, Ky., 1863. Special class of '84, Mass. Institute of Technology. Apprentice, Central Coal & Iron Co. (Central City, Ky.), Sept., 1883-April, 1893. Drawing-room, Engineers' Office (Central City, Ky.) with Central City Water Co., 1883-1893. Shop experience same, and Central City Planing Mill Co., 1883-1893. With Lorain Steel Co. (Johnstown, Pa.) and with Johnson Company. While connected with above companies, engaged in all kinds of work on the mechanical side or any other position in the operating end. Took out also a number of patents. Work in recent years has been along the executive lines, acting as Chief Engineer, Manager, etc. Present position, President, Johnstown Passenger Railway Co., E. I. DuPont de Nemours Powder Co., Central Coal & Iron Co., McHenry Coal Co., etc., etc.

References: Fred W. Taylor, Robt. W. Hunt, F. G. Tallman, J. H. Geer, M. M. Suppes.

JOSEPH EARTHOPE

JOSEPH EARTHOPE, 7534 Saginaw Ave., Chicago, Ill. Born Crane, England, 1859. Four years Mechanics Institute (Crewe, England). Apprentice, London & North Western, general mechanical work. Chief Engineer for Illinois Steel Company's South Works, Asst. Master Mechanic, and for past five years Master Mechanic, which is present position.

References: Geo. B. Bartlett, James Tribe, Edw. I. Hager, Louis Mohr, Edw. S. Black.

CHARLES COGGILL EGBERT

CHARLES COGGILL EGBERT, 52 Gluck Bldg., Niagara Falls, N. Y. Born New York, N. Y., 1874. Morris Academy, six years (Morristown, N. J.), Westminster School (Dobbs Ferry), and 5 years Cornell University; M.E., 1895. One year Swiss Federal Polytechnic (Zurich). Jan., 1897-Feb., 1899, Brooks Locomotive Works (Dunkirk), time divided between drafting-room, shop and experimental work. Engineer of Tests, Lehigh Valley R. R., Feb.-Oct., 1899. Nov., 1899-Jan., 1901, Chief Draftsman, Long Island R. R. Jan., 1901-Oct., 1902, Inspector of erection of mechinery Wheelpit No. 2, Niagara Falls Power Co. Oct., 1902-May, 1904, Engineer supervising design and construction of 10,000 H. P. turbines and other machinery built in Europe for Can. Niagara Power Co. Asst. Mechanical Engineer, May, 1904-Jan., 1905, in charge of erection of all machinery. July 1905, to date, Mechanical Engineer Niagara Falls Power Co., and Can. Niagara Power Co., engaged general consulting practice in connection with work of these companies.

References: Coleman Sellers, C. J. Carney, Phillip Wallis, S. H. Rippey, F. F. Gaines, G. S. Curtis.

NORMAN REESE ENTREKIN

NORMAN REESE ENTREKIN, 541 Chestnut Street, Coatesville, Chester Co., Pa. Born Coatesville, Chester Co., Pa., 1874. Apprentice, Baldwin Locomotive Works as machinist 1891-1895, tool room work, repair work and some machine work. Drawing-room, from fall 1895-1900, with North Bros. Co. (Coatesville, Pa., iron and steel manufacturers; head of drawing-room three years. Private lessons in drawing with Jno. S. Rooke on rolling mill machinery. Shop experience, Baldwin Locomotive works, night school Spring Garden Institute, in machine work,

on machine repairs, tool room work and engine work. With Worth Bros. Co. since 1895, during which time partly designed and entirely laid out, planned and erected the largest plate mill in the country. At present erecting another, in charge of all construction and maintenance in both mechanical and electrical departments, for Worth Bros. Co. and Coatesville Rolling Mill Co. Present position, Superintendent of mechanical and construction department for Worth Bros. Co. and Coatesville Rolling Mill Co.

References: J. M. Whitham, A. C. Wood, Warren Webster, J. E. Gibson, David Todd Jones.

DAVID COLTON FENNER

David Colton Fenner, Supt. Planning Dept., Sayles Bleacheries, Saylesville, R. I. Born Providence, R. I., 1875. Four years Mohegan Lake School (Peekskill, N. Y.); three years Sheffield Scientific School; two years Mass. Institute Technology, Ph.B., S.S.S., 1896; S.B., Mass. Inst. Tech., 1898. Apprentice, Bethlehem Steel Co., Dec , 1898-March, 1903, on Taylor-White tool steel and method of heat treatment. Shop experience, in charge of Crucible Steel Department, Bethlehem Steel Co. Built and operated plant for Adams Crucible Steel Co. after which engaged in commercial motor truck business until 1905, at which time became identified with Sayles Bleacheries to assist in reorganizing the management of same. Present position, Superintendent Planning Department Sayles Bleacheries.

References: F. W. Taylor, H. L. Gantt, Maunsel White. K. F. Wood, C. G Barth.

CHARLES S. FOLLER

Charles S. Foller, 616 Farmer's Bank, Pittsburg, Pa. Born Buffalo, N. Y., 1876. Buffalo public and high schools; Hobart College (Geneva, N. Y.), one year. Apprentice, Lake Shore & Mich. Southern Ry. (Buffalo), machinist trade. Drawing-room, American Locomotive Co. and Standard Steel Car Co., Oct., 1897-Sept., 1904. Shop experience, American Locomotive Co., assistant foreman machine shop. With exception of one year connected with designing department of the American Locomotive Co., years 1897-1905. May, 1900-Sept., 1904, principal designer of new locomotives at American Locomotive Co. One year engaged in designing steel cars with Standard Steel Car Co. (Pittsburg). At present, M. E. and Assistant Treasurer, Union Spring & Mfg. Co., engaged in manufacture of locomotive and car springs.

Rerefences: H. B. Ayers, Geo. M. Basford, Jas. E. Sague, Geo. T. Ladd, H. A. Porterfield., G. P. Robinson.

FRANCIS WILLIAM JACKSON

Francis William Jackson, care Wallace Stebbins & Sons, Contracting Engineers, Baltimore, Md. Born at Montreal, Canada. Seven years at Schools of the Christian Brothers, of Quebec and Kingston, Ont. Four years at Queens' University, Kingston, Ont.; degree of Bc.S. from Queens' University, 1898. Machinist trade with the Canadian Locomotive Co., Kingston, Ont., March, 8, 1888 to April 3, 1892, working on shaper, slotter, planer, lathe and vise. Feb., 1899 to Nov., 1899, tool designer with Canadian General Electric Co., Peterboro, Ont.; Dec., 1899 to May, 1900, draftsman with Watertown Steam Engine Co., Watertown, N. Y. Aug. 14, 1900 to Sept. 21, 1904 draftsman, designer and checker with Harrisburg Foundry & Machine Works, Harrisburg, Pa. Four years

apprentice, Canadian Loco. Co., Kingston Foundry & Machine Works, Oswego, N. Y.; April, 1893, to Sept., 1894 engine fitter at shops of Rome, Watertown & Ogdensburg, Railroad, Oswego, N. Y. When a student at Queens' University was made instructor in the mechanical laboratories for two sessions. 1902 to 1904 was the developing period of the new Fleming Harrisburg four-valve engine, the complete designs were checked and approved before drawings were distributed to the several departments of the Harrisburg Foundry & Machine Works. Harrisburg Foundry and Mach. Works, builders of the Fleming Engine is represented in Maryland, District of Columbia and Virginia by their Baltimore managers, Wallace Stebbins & Sons. For the past two years complete charge of the engine business for W. S. & S. Present position, mechanical engineer with Wallace Stebbins & Sons, Contracting Engineers, Baltimore, Md. Engaged in soliciting and superintending the installation of complete steam power plants.

References: B. T. Allen, W. E. Lindsay, M. E. Hershey, W. D. Young, E. C. Wiley.

ERNEST FUCHS

Ernest Fuchs, Box 334, Guadalajara, Mexico. Born Salzungen, Germany, 1860. Preparatory education, Realschule, Meiningen, and private instruction; awarded diploma and ensignia. Apprentice (Meiningen), construction of turbines in Germany and Chicago, Ill. Drawing-room, with G. Lotz, patent attorney, Morton Frog & Crossing Works, 1882; Chas. Kaestner & Co. (Chicago), 1885-1886, and since in own drawing-room. Shop experience, Chas. Kaestner, 1885-1886; designed and put up many flour mills, cotton gins and presses on own patent. 1881, superintended construction of turbines on father's inventions; invented lifting apparatus patented in the United States. Established with Chas. Kaestner (Chicago), in 1885, in charge of foreign department; director until 1888. Civil engineering work also in Chicago. Designed, sold and put up several mills in Lerdo, Mexico, since which time worked on own account in mechanical and civil engineer work and architecture. Nominated by government director of construction of Westside Water Works (Guadalajara), executing the system.

References: Schuyler Lawrence and By-Law B2.

ROBERT THOMAS GALLAGHER

Robert Thomas Gallagher, 12 Huntington Ave., Worcester, Mass. Born New York, N. Y., 1865. Nine years grammar schools; two years Worcester High School; 3½ years Worcester Polytechnic Institute. 1889-1896, Washburn & Moen Mfg. Co. (Worcester), power testing, fuel testing. 1897-1898, Crompton & Knowles Mfg. Co.; 1899-1901, American Steel & Wire Co., 1902-1906, Morgan Construction Co. 1900–1901, engineer on staff of chief engineer, American Steel and Wire Company with full responsibility as inspector of equipment and machinery contracted for by that company; responsible for examination of contract work under way, including steel buildings, furnaces, rolling mills, traveling cranes, etc. 1906, designer and director of force of draftsmen with Morgan Construction Co. Now Chief Draftsman and Designer in Engineering Department American Steel and Wire Company

References: J. R. George, V. E. Edwards, P. B. Morgan, E. H. Carroll, W. H. Morse.

M. McLEAN GOLDIE

M. McLean Goldie, W. H. Kidston & Co., Perth, W. Australia. Age 37. With Prof. Barr, Professor of Engineering, Glasgow University, for a period of 4½

years; and subsequently manager for Messrs. McGeoch & Co,, Ltd., Warwick. Works (Birmingham), thoroughly reorganized the whole of the engineering shops. At present, with W. H. Kidston & Company. Have carried out some of the largest contracts in Western Australia involving over 300,000 pounds, among these being the installation of electric light plant at So. Perth, Kanowna, Katanning, Subiaco, Claremont, extensions Boulder City, complete plant at Yallingup Caves, also Monteath's Foundry (Subiaco), Katanning Flour Mill, Perth Roller Flour Mill, Dargarup Saw Mill, Fremantle Tramways Power House equipment and numerous other undertakings. At present, in partnership with W. H. Kidston. & Co.

References: Jas. G. Winship and By-Law 2.

EDWIN JOSEPH HADDOCK

Edwin Joseph Haddock, 557 West 148th St., New York City. Born Mt. Vernon, N. Y., 1868. N. Y. Public schools and drawing course at Cooper Union and home study. Drawing-room, J. J. Claude-Mantle (New York), Feb., 1892-March, 1893. Shop experience, A. Weeks & Co. and Jos. Edwards & Co., 1889-1891. Draftsman, Thos. Edison, 1893-1894; Street Railway Co., 1894-1896. 1896-1900, designing briquetting and ore handling machinery for T. A. Edison and charge of design and erection of new buildings for the Edison Phonograph Works. 1900-1901, Chief Draftsman, Derby Lead Co. (Elvins, Mo.), designed crushing and concentrating plant. 1901-1902, on engineering force of the Illinois Steel Works (So. Chicago) and Heyl & Patterson (Pittsburg). Since 1902 with Robins Conveying Belt Co. Present position, Chief Draftsman Robins Conveying Belt Co.

References: Thos. A. Edison, Emil Herter, F. A. Phelps, James Craig, A. T. Nickerson.

JOHN LYELL HARPER

John Lyell Harper, Chief Engineer, Niagara Falls Hyd. Power & Mfg. Co. Niagara Falls, N. Y. Born Harpersfield, N. Y., 1873. M.E., Cornell University, 1897. Drawing-room, Oregon Improvement Co. (Seattle, Wash.), June to September, 1897. Shop experience, Union Electric Co., Sept., 1897-June, 1898. With Twin City Rapid Transit Co. (Minneapolis, Minn.), June, 1898-1899; testing 12,000 volt cables, operating 10,000 H. P. water power plant and making designs of switchboard and electric distributing systems. June-October, 1899, with W. I. Gray & Co. (Minneapolis, Minn.), making electrical designs of lighting and railway systems for Manhato (Minn.) with suburban electric railway connections. Oct., 1899-Sept., 1900, with Floy & Carpenter, Cons. Engrs. in charge of power station and electrical transmission system of plant for the St. Croix Power Co., for transmitting power 30 miles at 25,000 volt to St. Paul. Sept., 1900-May, 1901, Superintendent for St. Croix Power Co., operating plant and line. June-November, 1901, in charge of exhibit at Pan-American Exposition and doing consulting work. Present position, Chief Engineer, Niagara Falls Hyd. Power & Mfg. Co.

References: Jno. R. Freeman, R. C. Carpenter, W. C. Johnson, S. H. Rippey, Ralph D. Mershon.

A. HARTILL-LAW

A. Hartill-Law, Phœnix Foundry and Engine Works, Cairns, No. Queensland, Australia. Born England, 1859. Preparatory schools from 1866-1875, technical education, private tuition. Apprentice, John Rustal, Alma Tube Work-

(Walsall), with J. Northall, manager engine fitting, turning and pattern making, 1875-1880. Drawing-room, three years. Instructor machine construction and mechanical drawing, Rockhampton Technical College (Australia), 1887-1890. Shop experience, J. W. Sutton (Australia), general engineering. Other practical experience, Chief Engineer, Meat Works (Queensport), also Louisa Gold Mine; senior partner and manager of Law, Smith & Co., engineers and iron founders (Cairns). Now proprietor of Phœnix Foundry and Engine Works, patentee and sole maker of Hartill oil and gas engines.

References: (Applies under Foreign Rule—By-Law B-2.)

FRANK H. HAYES

Frank H. Hayes, 46 William St., Cambridge, Mass. Born Derby, Conn., 1848. Ordinary High School education. Apprentice at Derby, Conn. with John Whitlock, general machine shop, about 1876, on general work. Four-five years, Ball & Jewell, New York; two years stationary locomotive and marine engineering. Ten years locomotive work on the Naugatuck R. R. Hold New York City Stationary Enigneer's license. Hold Marine Engineer's License of Madison, Me. Management of erection of a water works plant for the Lowell Fertilizer Co., at Lowell, Mass.; installed a pumping engine for the City of Haverhill, Mass.; engineering for the North Packing and Provision Co.; the J. P. Squires Co.; The Dover Water Works of Dover, N. H., and for numerous other places. Employed by the Deane Steam Pump Co., Holyoke, Mass., in erecting pumping machinery at Montgomery, Ala.; Chippeaw Falls, Wis.; Merrill, Wis.; Staunton, Va.; Norfolk, Va.; Ware, Mass.; Hazelton, Penn. The above work covered a period of ten years. Manager of Boston office of Dean Steam Pump Co., for a period of eight years. Erected for Platt Iron Works Co., a complete pumping station for the Groton Water, Groton, Conn.; complete sewage pumping station, Pittsfield, Mass.; complete pumping station for Madison Water Co. Present position, New England Manager for Platt Iron Works Co., of Dayton, O.

References: Geo. H. Barrus, Francis H. Boyer, Thomas Hibbard, Edwin C. Brooks, F. H. Keyes, Albert C. Ashton.

ROBERT CULBERTSON HAYS HECK

Robert Culbertson Hays Heck, Lehigh University, South Bethlehem, Pa. Born Heckton Mills, Pa., 1870. M. E., Lehigh University, 1893. For nine years had charge of the course in Mechanical Technology which consists of a series of observation visits, mostly to the shops of the Bethlehem Steel Co., occupying summer term of four weeks. Engaged in teaching in M. E. Dept., Lehigh University, since graduation; Instructor 1893 to 1903, Assistant Professor since 1903. Summer, 1895, in Testing Laboratory, Bethlehem Steel Co. Summer, 1896, in drafting room, General Elec. Co., Schenectady. In special charge of design and installation of equipment of new Engineering Laboratory, 1901-1903. In charge of all Experimental Engineering work for 13 years. Literary work; Manual for the course in Eng. Lab. (partial). The Steam Engine and Other Steam Motors. Vol. I published in 1905. Vol. II nearly finished.

Rerefences: J. F. Klein, L. P. Breckenridge, H. C. Reist, H. B. Ayers, H. D. Hess.

HUGO ADELBERT HECKER

HUGO ADELBERT HECKER, Bellevue, Ky. Born Stepstone, Ky., 1866. Technical education, night school of Ohio Mechanics Institute. 1881-1885, apprentice, machinist with Wm. E. Leard milling machine work, fitter and foreman. 1887-1888, Drawing-room, Lane & Bodley Co., Corliss engines. 1888, Weir Frog Co., railroad frogs and switches, 3 mos. Bert L. Baldwin, M. E., 1888-1896. F. M. Watkins Co., gas engines, 1896-1897. Watkins Laundry Machine Co., 1897 to date. Shop experience, 1881-1885, Wm. E. Leard, U. S. Snagboat. E. A. Woodruff, repair work, 3 mos.; 1885, Lodge & Davis Machine Tool Co. 1886-1887, Lane and Bodley Co., 1887-1888. Further experience with Bert L. Baldwin, M E., as assistant draftsman on street railroad incline plane and power house work. F. M. Watkins Co., as chief draftsman. Design and testing of gas engines. Watkins Laundry Mach. Co., chief draftsman, design and construction of laundry machinery and modern laundry plants. Instructor in mechanical drawing for ten years at night school of Ohio Mechanics Institute. Present position, Chief Draftsman and advisory engineer to Works Manager.

References: J. C. Lemon, Ernst Richter, Geo. Horning, J. B. Stanwood, Walter Laidlaw, Bert. L. Baldwin.

RICHARD HENDERSON

RICHARD HENDERSON, Captain U. S. N. Retired, Salisbury, N. C. Born Salisbury, N. C., 1855. Nine years private schools; 4 years U. S. Naval Academy, 1872 1876; advance course in electricity, 1887-1888, at Torpedo Station (Newport, R. I). 1870-1872, owned and ran small machine shop and brass foundry; performed engineering duties at sea while midshipman and ensign, for about 4 years. 1894-1895, Professor of Physics, N. C. College of Agriculture and Mechanic Arts, (Raleigh N. C.), inaugurated course in electrical engineering; installed electric plant and wired the buildings; installed the electrical and physical instruments in laboratory. 1896-1899, on board the U. S. "Indiana" in charge of and personally operated a 13″ steam and hydraulic controlled turret. In charge of torpedo and air compressing plant, and automobile torpedoes. 1899-1901, member and recorder of the Board of Inspection and Survey on the trial boards of the new battleships and torpedo boats. 1901-1902, in charge of entire electric plant of battleship "Illinois." 1902-1904, executive officer of the U. S. S. "Alabama."

References: Albert Moritz, Walter M. McFarland, Ira N. Hollis, H. W. Spangler, M. E. Cooley.

RUDOLPH HERING

RUDOLPH HERING, 170 Broadway, N. Y. City. Born Philadelphia, Pa., 1847. Preparatory education, three years at Dresden, Germany, four years technical at Dresden, graduated as Civil Engineer in 1867. Chainman, rodman and leveler at Prospect Park, Brooklyn, 1868-1869; Asst. Engineer in Fairmount Park, Phila., 1869-1871; U. S. Geological Survey, exploration, of Yellowstone Park, 1872; Assistant City Engineer, Phila., 1873-1880; reported to National Board of Health on European Sewage Works, 1881-1883; Engineer in charge new water supply, Phila., 1883-1885; Chief Engineer of Chicago Drainage and Water Supply Commission, 1886-1887. 1888 to date, construction or consulting engineer for supply or sewage works in a large number of cities, including Boston, Providence, New York, Phila., Baltimore, Washington, Pittsburg, Buffalo, Cleveland, Colum-

bus, Indianapolis, Atlanta, Montgomery, New Orleans, Los Angeles, San Francisco, Oakland, Sacramento, Tacoma, Victoria, Winnipeg, Ottawa, Toronto, St. Johns, Honolulu, Santos, Brazil, etc. Now holds position of Consulting Engineer, Department of Water Supply, Gas and Electricity, New York City. Engaged in hydraulic and sanitary engineering expert work.

References: John R. Freeman, Chas. Whiting Baker, William J. Baldwin, John Thomson, Henry R. Towne, William H. Willey.

WILBUR GREGORY HUDSON,

Wilbur Gregory Hudson, Supt. Construction, Link-Belt Eng'g Co., Nicetown, Phila., Pa. Born New York City, 1875. New York Public Schools, College of the City of New York, and 2 years Cornell University, E. E., 1897. 1897-1898, rodman, levelman and transitman with Metropolitan Street Ry. Co. (New York). 1898, Assistant in Mechanical Engineering, Columbia University. 1899 to date, with Link-Belt Engineering Co., and the Dodge Coal Storage Co., at first in drawing-room and later on experimental work for one year with Mr. James M. Dodge; then resident engineer factories Dodge Coal Storage Plant. 1902–1906, in general charge of all erecting for Link-Belt Engineering Company, east of Ohio; at present in charge of all outside construction work Link-Belt Companies; superintendent construction Dodge Coal Storage Co., involving direct responsibility for construction and operation of work amounting annually to more than two million dollars.

References: James M. Dodge, Chas. Piez, C. E. Machold, Carl G. Barth, A. H. Riddell, S. Howard-Smith.

LEIGH ANSON HUNT

Leigh Anson Hunt, President Hunt Engineering Co., Iola, Kansas. Born Adrian, Mich., 1873. Drawing-room. Coldwater and Michigan (Portland), Feb., 1898-March, 1899. Cement Company as Chief Draftsman and Chief Engineer. Shop experience, Globe Eng. Works (Cleveland), 1892 and 1893. Oct., 1895, granted government license as marine engineer. 1896, 1st Asst. U. S. Marine Engineers license. Chief Engineer and Draftsman, Coldwater Portland Cement Works, 1898. Chief Engineer, American Construction Co. (Detroit), 1899 and 1900. General Superintendent Iola Portland Cement Co., 1900 and 1901 (Iola, Kansas). Consulting Engineer, Los Angeles, 1902. May, 1903, became President Hunt Engineering Co. (Iola), built Kansas Portland Cement Co., in 1903, rebuilt Western Portland Cement Co. (Yankton, Dakota), 1903-1904; double capacity Kansas Portland Cement Co., 1904; designed and rebuilding Independence Kansas Portland Cement Co., and doubling capacity Indian Portland Cement Co., 1906.

References: E. A. W. Jefferies, Thos. W. Capen, C. C. Christensen, W. E. Dodds, W. G. Starkweather.

HOBART STANLEY JOHNSON

Hobart Stanley Johnson, care Gisholt Machine Co., Madison, Wis. Born Madison, Wis., 1873. Madison High School; 3 years University of Wisconsin, 1890-1893. Apprentice, Gisholt Machine Co., on machine tools, 1893-1896, also considerable time in drafting-room. For several years past, general charge of drawing-room and factories of Gisholt Machine Company. Present position, 2d Vice-President and General Superintendent, Gisholt Machine Co.

References: W. F. Barnes, Storm Bull, E. P. Worden, F. L. Eberhardt, J. S. Detrick.

WILLIAM ANTHONY JONES

WILLIAM ANTHONY JONES, West New Brighton, S. I., N. Y. Born Nannet, Rockland Co., N. Y., 1872. M. E., Stevens Institute, 1894. 1894-1895, draftsman with Bement, Miles & Co. (Philadelphia). 1895-1898, at Drexel Institute as instructor in mechanical drawing, descriptive geometry, machine design and mechanics of machinery. 1898-1900, C. W. Hunt & Co. (West New Brighton), designing coal handling machinery. 1900 to date, with Babcock & Wilcox Co. (Bayonne, N. J.), laying out new plant and designing machinery for same. Present position, Mechanical Engineer, Babcock & Wilcox Co.

References: W. D. Hoxie, C. P. Higgins, M. W. Sewell, C. W. Hunt, James D. Andrew.

RICHARD D. KIMBALL

RICHARD D. KIMBALL, 6 Beacon St., Boston, Mass. Born Rochester, New Hampshire, 1847. Apprentice, Greenfield Tool & Machine Co. (Greenfield, Mass.), 1878-1881. Machine work, 1881-1887, Millers Falls Tool Co. (Millers Falls, Mass.). 1889-1891, Supt. Kimball Car Heating Co.(Boston). 1891-1893, representing Johnson Service Co., in New England. 1894-1895, Manager Mass. Heating & Vent. Co. (Boston). 1895-1896, with Braman, Dow & Co., private practice. Designed and installed under supervision of R. D. Kimball, heating, lighting and power plants as follows: Dartmouth College, Wellesley College, Mt. Holyoke College, Mass. Agr. College, Wells College, Middletown (Conn.), Insane Hospital, Northfield Seminary, Groton School, Berea College. Present, consulting engineer for above institutions; also College of the Holy Cross, Oberlin College, Middlebury College, Tufts College, University of Rochester, University of Maine, Wesleyan University, Norwich Insane Hospital, Mass. State Sanatorium and Phillips Academy; engaged in work for most of the above institutions and current work embraces Salvation Army Bldg. (Boston), Technical High School. (Providence), Malden High School, Winthrop High School, Floating Hospital Ship, Ford Bldg., Boston, and St. Paul's School, Concord, N. H. Have several patents for heating and mechanical devices.

References: Prof. G. C. Anthony, C. H. Chase, Thos. Cunningham, M.E. Hershey, Arthur C. Walworth.

CHARLES W. G. KING

CHARLES W. G. KING, 429 N. 13th Street, Philadelphia, Pa. Born Northampton, England, 1862. Apprentice, Peterborough, England. March, 1877 to April, 1883, Great Northern Railway Locomotive Department, on locomotives as fitter and erector also on machine tools for same. Student, South Kensington, science; continued in G. N. Rw. Co.'s service until October, 1887 as machinist. As machinist for about one year with Barr Pumping Eng. Co., Phila., Pa. As machinist for about 6 months with Wm. Sellers & Co., Phila., Pa., on electric cranes, and about 6 months with Bement & Co., Phila. on machine tool work. Entered the service of The U. S. Metallic Packing Co., as a draftsman, 1890; appointed chief draftsman, 1898, and superintendent, 1902. As chief draftsman had charge of designs of pneumatic hammers, metallic packing, pneumatic sanders; has also designed special machinery for the manufacture of the above, as grinding machine, drilling machine, etc. Also the laying out of shafting and machinery for new shops and superintending the installation of the same. Present position, Superintendent with full charge of shops and drawing-room in the United States Metallic Packing Co.

References: Chas. Longstreth, S. M. Vauclain, H. V. Wille, F. M. Whyte, Fred H. Colvin, H. L. Aldrich.

ALFRED RISTINE KIPP

Alfred Ristine Kipp, Fond du Lac, Wis. Born La Fayette, Ind., 1873. Three years at Indianapolis, High School, Ind. M. E., Purdue University, 1899. Special apprentice, with Penna. Line, M. P. Dep't. (Indianapolis), Aug., 1896-1899. Drawing-room, part of time during special apprenticeship, Penna. Lines, 1896-1899. Locomotive Fireman, Penna. Lines, Aug., 1899-1900. Special Inspector Motive Power, Penna. Lines, Columbus, Ohio, April, 1900-Feb., 1901. General Foreman, Locomotive Repairs, Penna. Lines, Dennison, Ohio, Feb., 1901-June, 1901. Present position, Master Mechanic, Wisconsin Central R'y, Fond du lac, Wis., June, 1901, to date.

References: Wm. F. M. Goss, J. G. Bower, T. S. Bailey, J. H. Mitchell, Justin Griess, Jr., M. J. Golden.

PAUL LANGER

Paul Langer, Techn. Hochschule, Aix la Chapelle, Germany. Born Austria, 1876. Gymnasium (Vienna, Austria) and graduate Techn. University, December, 1899. Assistant to Prof. Riedler at the Royal Techn. University (Berlin) 2 years. Designer with Morane, Jr. (Paris) for Riedler high speed pumps, 6 months. Assistant engineer in charge of mechanical engineering division of Bessemer Steel Works; rail and billet mill, Lackawanna Steel Co., 1 year. Designer with Allis-Chalmers Co., gas engine department, 2½ years. After May 1, 1906, Professor at Techn. Hochschule, Aix la Chapelle, Germany.

References: E. T. Adams, Max Rotter, C. G. Sprado, Max Patitz, W. G. Starkweather.

JOSEPH NISBET LE CONTE

Joseph Nisbet Le Conte, Mechanics Bldg., Berkeley, California. Born Oakland, California, 1870. B. S., 1891, University of California, M. M. E. 1892, Cornell University. For past fourteen years engaged in teaching engineering in the University of California, as assistant instructor and assistant professor. For past five years in entire charge of the department of hydraulics, design and construction of the laboratory for testing hydraulic machinery. Also agent and expert for the U. S. Department of Agriculture for testing pumping plants, for past three years. Present position, Assistant Professor of Mechanical Engineering, University of California.

References: John R. Freeman, Andrew M. Hunt, Howard Stillman, George J. Henry, Jr., Harris J. Ryan.

ROBERT LINTON

Robert Linton, Mining Engineer, Helena, Montana. Born Hudson, Ohio, 1870. Three years at Washington and Jefferson College. Two years at Imperial Institute of Technology, Charlottenburg, Germany. Degree of A. M., Washington and Jefferson, 1901. (Honorary Degree.) No apprenticeship. Have done considerable drawing from work in all positions held, but never engaged in this work exclusively. Assistant Engineer with McKinney & Smith (Pittsburg, Pa.); Assistant Engineer, Verreries Baudoux, Jumet (Belgium); Asst. Superintendent, R. C. Schmertz Glass Co. (Bellevernon, Pa.); Manager, American Window Glass Co.,

Factory No. 4. Assistant to Chairman, American Window Glass Co., Pittsburg, Pa. With McKinney & Smith engaged in surveying, drafting and construction work on coal mine equipment (2 years). In the three subsequent positions had the designing and building of various kinds of glass furnaces, as well as machinery used in the manufacture of window glass (10 years). In last position during a considerable portion of the time Acting Chief Engineer in charge of furnace construction and mechanical equipment (2 years). At present, special charge of mechanical equipment and installations in mines of which present firm has the management, as consulting engineer. Engaged in mining engineering, in partnership with R. M. Atwater, Jr., and M. W. Atwater.

References: Edward V. Wurts, C. G. Atwater, Carl D. Chasteney, Wm. C. Coffin, F. V. McMullin.

JOEL IRVINE LYLE

Joel Irvine Lyle, 39 Cortlandt St., New York City. Born Lexington, Ky., 1874. B.M.E., Kentucky State College; 1896, M.E., 1902. Apprentice, C. N. O. & T. P. Ry. shops (Ludlow, Ky.), machine and erecting shops,1896-1898. Drawing-room, at same time, Sept., 1898-Jany., 1899, and June-Sept., 1899. Shop experience, American Car & Fdy. Co., Shops (Jeffersonville, Ind.), as inspector for C. N. O. & T. P. Ry., January-June, 1899. Other practical experience, construction work Buffalo Forge Co. Sept.-December, 1899. 1900-1901, correspondence engineer Sales Department; 1901, Engineer, Sales Department, Syracuse Office, Buffalo Forge Co. At present, Manager New York office of same company. Designed and directed installation of heating and ventilating plants in General Electric Company's office building (Schenectady), Gorham Mfg. Co. (New York), L. V. R. R. Shops (Sayre, Pa.), B. R. & P. Ry. Shops (DuBois, Pa.), Criminal Courts Building (New York), High School (Waterloo, N. Y.), and drying installations Ithaca Wall Paper Co. (Ithaca, N. Y.), Standard Wheel Co. (Indianapolis, Ind.). Present position, Manager New York branch Buffalo Forge Co. and Buffalo Steam Pump Co., engaged in directing engineering sales and construction of heating and ventilating apparatus, mechanical draft apparatus, engines, steam and centrifugal pumps, fans, blowers and forges.

References: E. S. Farwell, W. J. M. Dobson, A. H. Blackburn, A. W. Cash, J. Henry Klinck.

PETER H. MacCORQUODALE

Peter H. MacCorquodale, 218 Coleridge Ave., Syracuse, N. Y. Born Canada, 1867. One year Mechanics Institute (Peterboro, Canada). Apprentice, W. M. Hamilton Mfg. Co., 1883-1886, marine and stationary engines, mill machinery, etc. 1886-1888, Detroit Dry Dock Engine Co. (Detroit, Mich.), as machinist. 1888-1889, Detroit and Cleveland Steam Navigation Co., as assistant engineer on steamer "City of Cleveland." 1889-1890, with Detroit Dry Dock Engine Co. 1890-1891, Genl. Foreman, Eagle Iron Works (Detroit, Mich.), builders of marine and stationary engines. 1891-1892, Foreman, Erie Forge Co. (Erie, Pa.). 1892-1894, Foreman, Murphy Iron Works (Detroit), marine and stationary engines, also automatic stokers. 1894-1896, with J. B. Wilson grain elevator work, also Fisher Electric Co., engines and dynamos. Present position, Master Mechanic, in charge of design and operation of plant, Church & Dwight Co. (Syracuse), 1896-1906, care plant manufacturing soda.

References: Albert Stearns, Jno. E. Sweet, F. G. Chambers, E. D. Church, Jr., Geo. G. Cotton.

WALTER MacGREGOR

WALTER MACGREGOR, M. E. American Steel Foundries, Sharon, Pa. Born Michigan, 1876. 1903, M. E., University of Michigan; 1891-1896, apprentice at stationary steam engineering with Hardgraves and Turner and Fisher saw mills at Bay City (Mich.). Drawing-room, American Radiator Co. (Detroit); Brown Hoisting Machine Co. (Cleveland); Whiting Foundry Co.; American Steel Foundries and United States Eng. Corps, June, 1904-August, 1904. Shop experience, American Radiator Co., June, 1901-1902; as asstistant foreman of machine shop. Early experience secured as millwright and steam engineer in various saw mills at Bay City, Mich. 1900, construction of dam for U. S. Engineer Corps (Batesville, Ark.), also as head draftsman on same lock and dam for six months before construction work was started. Subsequent experience, designing new steel foundry for American Steel Foundries Co. (Chicago), June, 1903-August, 1904; then made construction engineer, which is present position, reporting direct to the 1st Vice-President. Completed Company's new plant at Indiana Harbor (Ind.); rearranged and modernized the company's plants at Chester, Pa., and Sharon Pa., in entire charge of both designing and construction; work included considerable power plant work, electric crane work, open hearth furnace work, annealing furnace work, fuel oil systems, gas producer work and steel buildings.

References: M. E. Cooley, Jno. R. Allen, Geo. R. Brandon, W. L. Miggett, W. Morava.

ARTHUR ROYAL McARTHUR

ARTHUR ROYAL MCARTHUR, 1532 South J Street, Elwood, Indiana. Born Rock County, Wis., 1873. Three years Milton College, (Milton, Wis.); 4 years University of Wisconsin (Madison), B.M.E., 1900. 1900-1901, drafting and general designing, American Sheet and Tin Plate Co. (Elwood, Ind.) Six months, 1901, master mechanic, American Sheet and Tin Plate Co., Atlanta Works (Atlanta, Ind.) 1902, general construction work and supervision over boiler plant at American Works. 1903-1904, original designing of machinery and furnaces and Chief Draftsman for American Works. 1905, Chief Engineer and supervision over district construction work. 1906, District Engineer, American Sheet and Tin Plate Company, general supervision of mechanical force and machinery of following works, American, Morewood, Anderson, Midland and Piqua.

References: C. W. Bennett, Storm Bull, C. W. Bray, J. G. D. Mack, D. C. Jackson.

DERMOT McEVOY

DERMOT MCEVOY, 35 Bishop Street, Montreal, Quebec. Born Birmingham, England, 1871. Four years King Edward's Grammar School. Apprentice, Birmingham Central Tramways Co., machine shop and erection work, 1886-1889, rebuilding and testing high pressure steam locomotives. Drawing-room, Polson Iron Works (Toronto, Canada), 1889-1891; Walker Mfg. Co. (Cleveland), 1891-1892; 1892-1894, Buffalo Engineering Co.; 1894-1895, Canadian General Elect. Co. (Peterborough, Canada); 1895-1896, B. F. Goodrich Co. (Akron, Ohio); 1896-1903, Gutta Percha and Rubber Mfg. Co. (Toronto); 1903-1906, Canadian Rubber Co. (Montreal). 1889-1891, Polson Iron Works, marine and stationary steam engines, fitting and erecting engines for S. S. "Seguin," S. S. "Ontario" and Brown automatic. Remodeling the Gutta Percha and Rubber Works (Toronto), including design and installation of complete electric lighting system and special rubber drying apparatus. Remodeling works of the Canadian Rubber Co. (Mon-

treal), which is still in progress. Present position, General Mechanical Superintendent, Canadian Rubber Co.

References: Frank H. Brewster, C. M. Morse, E. C. Shaw, C. M. Morse, A. C. Larkinm, D. R. Bowen.

LOUIS H. MARTELL

Louis H. Martell, Mgr. M. P. Dept., The Garlock Packing Co., Ellwood City, Pa. Born Nova Scotia, 1864. Apprentice, Michigan Central R. R. Co. (Jackson, Mich.), Aug., 1881-Jan., 1884. Drawing by home study and night schools, filling draftsman's position while working as machinist. Shop experience, Geo. D. Walcott & Son, 1884-1885. Machinist at Hinkley Locomotive Works (Boston), and many other shops in all lines of work, mostly in vicinity of Boston. Engineer on steamers "City of Lynn," "Longfellow," fireboat City Fire Department and others. 1895, with Wm. B. Merrill & Co. (Boston), engaged in manufacture of metal packing for piston rods and valve stems; since which time made that line a specialty. 1902, organized the Pitt Mfg. Co. (Pittsburgh, Pa.), for manufacture and sale of complete line of metal packing in entire charge of equipment, design and manufacture of product 1903, new factory at Ellwood City (Pa.), equipped with special tool of own design 1905, Garlock Packing Co. assumed lease of Pitt Mfg. Co.'s plant, applicant being in charge as manager of the Metal Packing Department.

References: R. C. Stiefel, C. N. Scott, H. R. Cornelius, C. E. Sargent, E. P. Coleman.

THEODORE HARRY MILLER

Theodore Harry Miller, 16 Lafayette Place, Poughkeepsie, N. Y. Born Mechanicsburg, Ohio, 1872. Apprentice (Richmond, Ind), Robinson Machine Works, Mar., 1888-June, 1891. Continuous shop work from apprenticeship to March, 1895, with Richmond Machine Works (Richmond, Ind.), Warder Bushnell & Glessner (Springfield, O.), The Saml. T. Moore & Sons Co. (Elizabethport, N. J.), The Brady Mfg. Co. (Brooklyn, N. Y.), and The Mergenthaler Linotype Co. (Brooklyn). March, 1895-June, 1899 with Mergenthaler Linotype Co. (Brooklyn), in charge of experimental department and gage department. 1899-1900, Superintendent in full charge of Elliott & Hatch Book-typewriter Works (Brooklyn). 1900-1901, Superintendent in full charge of Utica Forge & Tool Co. January 1903, to present time, Superintendent of The deLaval Separator Works, engaged in manufacture of cream separators, in general charge of entire plant.

References: Fred J. Miller, Elmer H. Neff, John E. Sweet, Edw. S. Lea, Fredk. Hart.

JOHN NORRIS MOWERY

John Norris Mowery, 432 Seneca St., S. Bethlehem, Pa. Born Strasburg, Pa., 1873. Four years Franklin and Marshall College, B.A., 1895; A.M.,1899; M. E., Cornell University, 1899. Apprentice, C. B. & Q. R. R., July, 1899-May, 1900, on erecting floor and in machine shop. June 3, 1902-April, 1903, American Locomotive Co. (Schenectady), elevation work; April, 1903-Feb., 1904, N. Y. C. & H. R. R. R., Motive Power Dept., and Feb., 1904-March, 1905, West Albany Shops. May, 1900-June, 1902, Heyden Water Purifier and Heater Co., traveling engineer, working on water purification and installing Sweeney exhaust nozzles in locomotives; March-July, 1905, piece work inspector. N. Y. Central and Hudson River R. R., West Albany Shops, July, 1905-February, 1906, in charge of dynamometer

car work. Present position, Mechanical Engineer, Lehigh Valley Railroad, having particular reference to designing of new power and rolling stock, together with improvements in old equipment.

References: A. E. Mitchell, Angus Sinclair, C. H. Quereau, R. C. Carpenter, Wm. R. Park.

HAROLD P. NORTON

HAROLD P. NORTON, Bureau Steam Engineering, Navy Department, Washington, D. C. Born New York, N. Y., 1855. Graduated as Cadet Engineer, U. S. Naval Academy, 1879. Commissioned Assistant Engineer, U. S. N., 1881, Chief Engineer, 1899. Duty as Engineer, officer at sea. Shore duty at Bureau of Steam Engineering, Navy Dept. (Washington, D. C.). Inspector of Machinery at John Roach's Quintard Iron Works, Sir Wm. Armstrong, Whitworth & Co., and Hawthorn, Leslie & Co. (Newcastle-on-Tyne, England). Dept. of Steam Engineering, Navy Yard, Brooklyn. Present, in charge of designing and drafting room, Bureau of Steam Engineering, Navy Department.

References: Walter M. McFarland, George W. Melville, Charles H. Manning, Wm. D. Hoxie, Wm. H. Bailey.

JOHN THOMAS RAMSDEN

JOHN THOMAS RAMSDEN, 2646 North 17th Street, Philadelphia, Pa. Born S. Easton, Pa., 1859. Apprentice, mechanical drafting Wm. Sellers & Co. (Phila.), Dec., 1878-Nov., 1880, on drawings of machine tools. 1878-1900, apprentice, draftsman and designer of machine tools with Wm. Sellers & Co. Sept., 1900-June, 1905, Chief Draftsman and since that date Assistant Mgr. for the Tabor Mfg. Co. (Phila.); awarded diploma and bronze medal as "special prize" for metal work in the night classes at the Spring Garden Institute, 1895. During time with Wm. Sellers & Co. had also considerable experience designing boring and turning mills, lathes and drill presses of every description. Original designs of double frame slotting machine and spacing mechanism for punching machinery. Present position, Assistant Manager for the Tabor Manufacturing Co.

References: Wilfred Lewis, Harris Tabor, Coleman Sellers, Jr., S. L. Kneass, Carl G. Barth.

WILLIAM NEWTON RYERSON

WILLIAM NEWTON RYERSON, Box 4, Niagara Falls, N. Y. Born New York City, 1874. E.E., Columbia University, 1896. Apprentice, Sprague Electric Elevator Co. (Watsessing, N. J.), with E. R. Carrichoff, E.E., electrical testing and drafting, Nov., 1896-Jan., 1898. Drawing-room, Sprague Electric Co., and Western Electric Co. (New York), with latter company, January-June, 1898. Metropolitan Street Railway Co. (New York City), 1898-February, 1901, as construction laborer, switchboard operator in substations and power station, foreman of substation and assistant to assistant electrical engineer. Chief Operator, 74th Street Power Station, Manhattan Railway Co., Feby.-October, 1901. Then superintendent of substations for the company and also Interborough Rapid Transit Co., until April, 1905. In charge of all substation construction operation and considerable designing, testing and experimental work, being solely responsible for all latter work. Present position, Superintendent Ontario Power Co., Niagara Falls.

References: H. G. Stott, C. R. Pratt, J. D. Andrew, P. N. Nunn, H. Torrance.

TANOSHI SAKA

TANOSHI SAKA, Kawasaki Dockyard Company, Kobe, Japan. Born Tokio, Japan, 1854. Six years at Engineering College, Tokio. Apprentice, (Akabane, Tokio), mechanical general works, April, 1880-March,1882, pattern, casting, forging, turning, and fitting shops. Drawing-room and work cotton spinning machinery of 2000 spindles, taking 1½ years to complete same at Akabane Works; steam engines of 150 H. P., 2 months in completion and other minor work. Foreman erection 4" gun carriage, Nordenfelt machine guns at Tokio Naval Arsenal. 1886, became Chief Engineer Kawasaki Dockyard, designed and made all kinds of marine engines, 120 in number, also iron structures for building, hoisting engines land boilers, condensing engines for factory, electric engines, etc. Present position, Chief Engineer of Kawasaki Dockyard.

References: Gompei Kuwada. (Applies under B. 2).

WILLIAM LAWRENCE SAUNDERS

WILLIAM LAWRENCE SAUNDERS, President Ingersoll-Rand Co., 11 Broadway, New York City. Born Columbus, Ga., 1856. B.S., University of Pennsylvania, 1876. 1878, in charge of hydrographic work for National Storage Co. (Communipaw, N. J.). 1879-1881, dredging and subaqueous rock excavation for national Storage Co. Invented, patented and perfected apparatus and methods for drilling rock under water which are now in general use. As Engineer, Ingersoll Rock Drill Co. invented, patented and perfected the Ingersoll track channeler for quarrying dimension stone, marble, sandstone, etc.; invented and patented the bar channeler. Eighteen years, Secretary and Engineer, Vice-President and President Ingersoll-Sergeant Drill Co., and Vice-President Haeseler Pneumatic Tool Co. Present position, President Ingersoll-Rand Company. Editor and publisher "Compressed Air" and "Cyclopedia of Compressed Air Information."

References: H. H. Suplee, O. C. Wolf, David Townsend, C. H. Sergeant, Wm. Prellwitz.

WILLIAM SAXON

WILLIAM SAXON, Oak Park, Ill. Born Christiania, Norway, 1857. Graduate technical course, Mechanics Institute, Manchester, England. Apprentice, machinist's trade, Parr, Curtis & Co., Manchester, Eng., 1872-1877, on all the different branches of machine shop work. Drawing-room, 1877-1882. Employed in Norway as machinist and draftsman at J. & A. Jensonn & Pahl, and O. Ousum Co. 1883-1887, with McGregor & Co., Chicago, as draftsman and machinist on steam engines. 1887-1889, shop foreman with C. Spearm (Chicago), printing press work. 1889-1891, with S. K. White (Chicago), as machinist and foreman, general repair work, Since 1891, General Superintendent for the Miehle Printing Press and Mfg. Co. (Chicago).

References: P. M. Chamberlain, C. E. De Puy, Allan Ransom, W. L. Cheney, G. H. Smith.

CARL H. SCHLACHTER

CARL H. SCHLACHTER, 266 Harrison St., Passaic, N. J. Born Gindau-Bodensee. Germany, 1873. M. E., Technical University, Munich, 1897. Apprentice, (Brackwede, Westfallen, Germany), K. & Th. Moeller, engine builders and boiler makers, 1892-1893. Drawing-room, The Watts Campbell Co., engine builders (Newark, N. J.), 1898-1899. After receiving M. E. diploma in Munich worked with Botany Worsted Mills (Passaic, N. J.), making tests on boilers and engines,

designing new machinery for manufacturing woolens and worsted goods. From April, 1899, to Oct., 1900, was assistant to Prof. Von Grove at the Technical University, Munich, helping students in drawing-rooms to design steam engines, water turbines, pumps. Since Nov., 1900, with the Botany Worsted Mills. In 1904, supervised the mechanical part in erection of a new mill, The Forstmann & Huffman Co., connected with the Botany Mills. Member of the "Verein Deutscher Ingenieure," since 1898. Present, Superintending Engineer, Botany Worsted Mills, Passaic, N. J.

References: D. D. Jacobus, J. H. Abercrombie, J. W. Ferguson, Robt. E. Hall, George W. Campbell.

DWIGHT SEABURY

Dwight Seabury, 12 East Ave., Pawtucket, R. I. Born Providence, R. I., 1863. Apprentice, Thompson & Nagle (Providence), mechanical engineering and architecture, July, 1881, for three years, general mill construction. Drawing-room, B. B. & R. Knight, Providence mills, 2 years; F. P. Sheldon, mill engineer, (Providence), 9 years; in charge of office 3 years. Installed power plant for Callender, Mcauslar & Troup Co. (Providence); designed and equipped mills 2 and 3 of Royal Weaving Co. (Pawtucket), also Portland Silk Mill (Middletown, Conn.); Brighton Mills (Passaic, N. J.); Pennekees Mills (Valley Falls, R. I.); E. Jencks Mfg. Co., (Pawtucket, R. I.); A. T. Athetton Machine Co. (Pawtucket); G. W. Parks Co's building (Providence). At present in own business as mill engineer and architect, Pawtucket, R. I.

References: Edwin R. Bullock, C. E. Giles, B. G. Buttolph, E. D. Pingree, Wm. L. Lyall.

CHARLES EDWIN SEARCH

Charles Edwin Search, Niles-Bement-Pond Co., Hamilton, Ohio. Born Milwaukee, Wis., 1867. Apprentice, E. P. Allis Co., 1884. Drawing-room, Allis-Chalmers Co., in charge of equipment and department, 1901-1904. Shop experience, Allis-Chalmers, 1884-1900. Other practical experience, core making one year, brass moulding six months, and iron foundry six months. Assistant foreman, two years; general foreman, four years; designed special tools for Allis-Chalmers Co., charge of all equipment and construction work of the company from 1900-1904, including West Allis Shops under direction of Mr. Edwin Reynolds. Present position, in charge of improvements, additions and equipments, Niles-Bement-Pond Co.

References: R. C. McKinney, Jas. K. Cullen, Walter L. Clark, B. M. W. Hanson, Francis C. Pratt.

FRANK EDSON SHEDD

Frank Edson Shedd, Lockwood, Greene & Co., 93 Federal Street, Boston, Mass. Born Sharon, N. H., 1856. B.S., Dartmouth College, June, 1880. Engaged on U. S. Coast and Geodetic Surveys, coast of Maine in year 1881. With M. B. Smith (Lowell, Mass.), three years on surveying, civil engineering and construction work as first assistant, 1881-1884 inclusive. One year similar work in Boston in 1885. Resident Engineer on construction Washington Mills (Lawrence, Mass.), 1886. With Lockwood, Greene & Co. since April, 1887, engaged in supervision of all construction work and of equipment, particularly of the power plants; also in charge of hydraulic work, electrical transmission and motive power for many cotton and woolen mills, machine shops and foundries which have been

designed and built by firm. Since 1902, Vice-President and Chief Engineer, Lockwood, Greene & Co.

References: John R. Freeman, Geo. H. Barrus, Richard H. Rice, Walter B. Snow, Wm. Lee Church.

ROBERT SHIRLEY

Robert Shirley, P. O. Box 64, West Hartford, Conn. Born Glasgow, Scotland, 1869. Education, Hutchison's Preparatory and Technical College, Glasgow. Passed Government examinations in applied mechanics, steam and the steam engine, machine construction and drawing, and mathematics. Apprentice, Wm. Dixon & Co., Ltd., drafting, patternmaking, moulding, also in machine and blacksmith shop, 1886-1892. Drawing-room, Wm. Dixon & Co. (Scotland), and Rensselaer Co. (Cohoes, N. Y.), 1886-1901. Shop experience, Wm. Dixon & Co., R. Napier & Sons. With the Rensselaer Mfg. Co. (Cohoes, N. Y.), designing valves and special tools for machinery, in sizes from ½″ to 72″, and having special and original features for which applicant was responsible, having general oversight of the work. Present position, Mechanical Engineer, Pratt & Cady Co. (Hartford).

References: Wm. H. Honiss, A. W. Cash, Henry Souther, C. E. Billings, E. H. Mumford.

ROBERT JAMES OSBORNE SIMPSON

Robert James Osborne Simpson, 132 Green Street, Athol, Mass. Born Toronto, Canada, 1868. Apprentice, J. Gibson (Toronto), general mechanical work, 1882-1887. Shop experience, Leland Faulconer Co., 1891-1896, 1890-1901. For past twelve years in responsible charge of results obtained from special devices, including special machinery and fixtures of own design. Present position, Superintendent and Mechanical Engineer, L. S. Starrett Company.

References: Jno. McGregor, T. Farmer, E. R. Fellows, F. C. Wells, H. M. Leland.

PETER SEVERIN STEENSTRUP

Peter Severin Steenstrup, 427 Middlesex St., Harrison, N. J. Born Norway, 1874. Six years high school, 3 years Preparatory Gymnasium State University, Norway. For past five years associated in management of the Hyatt Roller Bearing Co. (Harrison), during which time being closely in touch with and assisted in bringing to the highest point the anti-friction bearings; at different times in entire charge of various departments, both manufacturing and administrative. Made number of radical improvements in design the most important of which has been patented. Present position, Secretary and Manager of Sales Department which calls for constant study into the mechanical principles involved in manufacture of anti-friction devices and in charge of technical advertising campaign.

References: H. A. Carpenter, H. B. Binsse, Gardiner C. Sims, A. L. Williston, F. C. Billings, N. H. Harrington.

CHARLES P. STEINMETZ

Charles P. Steinmetz, Union University, Wendall Ave,. Schenectady, N. Y. Born Breslau, Germany, 1865. Five years University Breslau; 1 year Polytechnician (Zurich), A. M. (honorary), from Harvard, 1902; Ph.D. Union University, 1903. Draftsman, designing engineer and investigator, Osterheld & Eickemeyer Mfg. Co. (Yonkers), 1889-1893. Designing engineer, General Electric Co., 1893.

Present position, Cons. Engineer General Electric Company, and Professor Electrical Engineering, Union University.

References: W. L. R. Emmet, O. H. Landreth, W. B. Potter, H. G. Reist. E. Griffin, J. W. Lieb.

JAMES HUGHES STRATTON

James Hughes Stratton, 40 Hulburt Ave., Akron, Ohio. Born Atwater, Ohio, 1862. Apprentice, Webster, Camp & Lane Mach. Co., Akron, O., 1880-1883. Drawing-room, Webster, Camp & Lane (Akron, O.), M. C. Bullock Co. (Chicago), Cummer Engine Co. (Cleveland), 1883-1886. Shop experience, Webster, Camp & Lane, 1886-1889. From 1889-1893 with Webster, Camp & Lane as general draftsman, salesman and in charge of erection of hoists and mining machinery. 1893-1898, Chief Draftsman with Webster, Camp & Lane Co. designing and installing Hornburg car dumper at Sandusky, Ohio. 1898-1903, Chief Engineer of Webster, Camp & Lane Co. in charge of designs, making estimates and specifications on general machinery. 1903-1905, Engineer with Wellman, Seaver, Morgan Company. Present position, Engineer of Construction with Wellman, Seaver, Morgan Co. (Cleveland).

References: S. T. Wellman, S. H. Pitkin, J. S. Lane, Jno. McGeorge.

MAX JULIUS ULRICH

Max Julius Ulrich, Alberger Condenser Co., 95 Liberty St., N. Y. City. Born, Halle, Germany, 1856. Educated at Royal Technical Institute (Halle), and graduate Polytechnic Institute (Carlsruhe). Apprentice, (Leipzig, Germany) Emil Stachrer, 1870-1873. Drawing-room, W. Uhland (Leipzig), 1873-1874. Shop experience, (Rosslau) Sachsenberg Bros., one year as machinist, building mining machinery. Designer for Messrs. Haddick & Roethe (Weissenfels, Germany), pump makers, 1879-1881. 1882-1894, designer for the Deane Steam Pump Co. (Holyoke, Mass.), with exception of three years. 1894-1901, Chief Draftsman of same company. 1889-1892, Supt. and M. E. of the Ulrich Engine Co. (Florence, Mass.). Inventor of cut-off for duplex steam pumps, patented in U. S. A., England and Germany. Since September, 1902, with Alberger Condenser Co. (N. Y. City). Present position, Chief Draftsman.

References: Louis R. Alberger, Thos. Hibbard, Edgar Penney, W. P. Dallett, Chas. L. Griffin.

HENRY C. VAN BUSKIRK

Henry C. Van Buskirk, 1028 Emerson Street, Denver, Colo. Born Bloomington, Ill., 1869. Public schools and private instruction. Apprentice, Chicago & Alton Shops (Bloomington, Ill.), general locomotive construction, 1886-1890, in general railway shop work. Shop experience, Chicago & Alton Ry., Wabash, Rock Island, Fort Worth & Denver City, and Colorado & Southern railways. Installed electric lighting plant (Wymore, Nebraska), 1893-1895. Present position, Superintendent of M. P., Colorado & Southern Railway, supervising locomotive and car departments of the Colorado & Southern.

References: John H. Mitchell, J. G. Bower, W. E. Symons, W. A. Nettleton, Spencer Otis.

PERCY VENABLES VERNON

Percy Venables Vernon, Engr. Penvorn Manor Road, Coventry, England. Born Manchester, England, 1871. Five years Manchester Grammar School, partly

scientific and technical. Six years Manchester School of Technology, engineering classes. Member of the Institute of Mechanical Engineers. Apprentice, Kendall & Gent Machine Tool builders, 1887-1892, lathe one year, fitting and erecting 3 years. Drawing-room, 1891-1896, Kendall & Gent (Manchester), Machine tool makers. 1896-1897, Babcock & Wilcox, Ltd. (Scotland), as special tool and machine designer. 1897 to date, Alfred Herbert, Coventry, England. Babcock & Wilcox, special tool designed, holding responsible position under Chief Engineer, designing special labor saving machinery for Babcock boilers; hanging presses, special drilling machines, hydraulic work, in responsible charge of own design. Present position, Chief Designer machine tools, Alfred Herbert, Ltd.

References: W. A. Hildreth, Henry D. Sharpe, W. R. Warner, Fred J. Miller, James Hartness.

CHARLES VAN CISE WHEELER

Charles Van Cise Wheeler, Room 23, Home Life Bldg., Washington, D. C. Born Berea, Cuyahoga Co., Ohio, 1866. Two years preparatory school, Western University of Pennsylvania. Six months, 1884, with Hussey, Howe & Co. (Pittsburg), millwright. 1885-1888, with Sterling Steel Co. (Demmler, Pa.), working as helper to hammermen, blacksmiths, firemen, melters and millwrights. 1888-1890, Detroit Steel and Spring Works, superintendent of Tool Steel Department. 1890-1891, with W. J. Haines & Co. (Phila.), as steel salesman visiting machine shops in Eastern territory. 1891, six months with Cleveland-Brown & Co. as steel salesman visiting machine shops in Ohio territory. 1891-1897, with Sterling Steel Company as superintendent of works, responsible charge of manufacture of tool steel and projectiles. 1897 to present, with Firth-Sterling Steel Company, (Demmler, Pa.), as superintendent of Projectile Department; also with A. G. McKenna, Mass. Institute of Technology, investigating principles of design of projectiles for perforating armor plate along original lines. Development of type of same in scientific manner so as to raise requirements by the government. 1st, shells to pass on Krupp plate instead of Harvey; 2d, shells to remain unbroken instead of merely all parts through; 3d, capacity of chamber for explosive doubled, and 4th, shells required to explode with satisfactory fragmentation. Present position, Superintendent Projectile Department, Firth-Sterling Steel Company, at present building new Ordnance Works for same company in District of Columbia doing the engineering work for same.

References: Henry I. Lea, Geo. Mesta, A. M. Saunders, Wm. J. Hagman, Jno. W. Seaver.

GEORGE HENRY WHITE

George Henry White, 4 Lincoln Street, Oil City, Pa. Born Staffordshire, England, 1851. Apprentice, Hughes & Hughes Tube Works, (England), 1865-1870, lathes and other tools. Made drawings for Crescent Tube Works (Pittsburg), 1870-1872, built and erected above machinery. Designed and built Cleveland Tube Works in 1873. Rebuilt and superintended Continental Tube (Pittsburgh), 1884-1886. Designed and built Oil City Tube Works, 1887-1894. Superintendent of Oil City Boiler Works, 1894 to present time, which is present position.

References: Jos. Reid, Wilber O. Platt, A. B. Steen, Edw. Leighton, C. J. Carew.

HUGH HEATHLEY WILSON

Hugh Heathley Wilson, Master Mechanic Ontario Power Co., of Niagara Falls. Born Mayesville, S. C., 1867. Apprentice, Cheraw Iron Works (Cheraw,

S. C.), 1887-1890; shop experience, Athem Foundry & Machine Works, Morgan Iron Works, U. S. Navy Yard (Norfolk), 1890-1894. After finishing apprenticeship, one year with Athem Foundry & Machine Works as road engineer, 1890-1891. 1891-1903, General Foreman, Morgan Iron Works (Spartanburg, S. C.). 1893-1894, steam engineering department, U. S. Navy Yard (Norfolk). 1893-1897, in service of U. S. Navy. 1897-1898, Westinghouse Elec. & Mfg. Co. 1898-1900, Chief Engineer Colorado Elec. Power Co., during which time in charge of installation of generating station. 1900-1901, mechanical superintendent Union Gold Extraction Co. 1900-1905, had charge of motive power Westinghouse Elec. & Mfg. Co. 1905 to present time, Master Mechanic, Morgan Construction & Power Co., during which time in charge of mechanical installation.

References: W. M. McFarland, P. A. Lange, E. S. McClelland, Paul N. Nunn, John C. Parker.

OSCAR WINTER

Oscar Winter, 232 East Sixth St., Elyria, Ohio. Born Eheleben, Germany, 1865. Apprentice, Frankenhausen (Germany), with the Marktscheffel Iron Works, 1879-1883. Drawing-room, part of time during apprenticeship, 1879-1883. Shop experience, Krupp Steel Works (Germany), 1883-1884. Assistant Engineer Clyde Steamship Co., 1884-1892. Assistant Engineer American Line from 1892-1893. Chief Engineer N. Y. and Cuba Mail Steamship Company 1893-1894. Chief Engr. Clyde S. S. Co., 1894-1897. With Edison Electric Illuminating Co. (New York) as Chief Engineer of the second district from Sept., 1897-1899. Chief Engineer New York and Texas Steamship Co. April, 1900-March, 1901. 1905, elected member of the "Verein Deutscher Ingineure" (Berlin). Present position, steam engineer National Tube Co. (Lorain, O.) since April, 1901, engaged in indicating engines, conducting conducting tests of boilers, engines and other machinery.

References: M. M. Suppes, Herbert C. Ryding, Edgar Piercy, Ralph Crooker, Jr., Thos. H. Mirkel, Jr.

FOR PROMOTION TO MEMBERS' GRADE

EDWIN EBERT ARNOLD

Edwin Ebert Arnold, Engineer assisting Vice-President Westinghouse Machine Co., E. Pittsburgh, Pa. Born Zanesville, Ohio, 1876. M. E., Ohio State University, 1898. Since taking degree engaged continually with the Westinghouse Machine Co. (E. Pittsburgh), in various capacities. Entered shops and engaged in testing work, later transferred to drafting room and engineering department, doing original designing, principally of gas engines. Present position, Engineer Assistant to Vice-President.

Elected Junior Member, May, 1900.

References: E. E. Keller, Arthur West, H. E. Longwell, E. S. McClelland, H. L. Barton.

WILLIAM SUMMER AUSTIN

William Summer Austin, Westinghouse, Church, Kerr & Co., 10 Bridge St., N. Y. City. Born Morton, N. Y., 1871. M.E. in E.E., Cornell, 1896. Drawing-room, W. H. Brenner, N. Y. and Staten Island Electric Co. Entire charge of erecting boiler plant at Danville, Ill., for Westinghouse, Church, Kerr & Co., and pulp and paper mill at Covington, Va. Under W. W. Churchill, in charge of design and construction of Detroit Edison's Company's 15,000 kw. station; 8000

kw. Westinghouse service power plant of the Hartford Light Co.; 3000 H. P. station of The Terminal Railway Association (St. Louis), and East St. Louis Shops for the same company. 2,500 kw. power-house Erie Railroad (Hornellsville), and work in the shop buildings; boiler plant of the Columbian Cordage Company (Auburn, N. Y.), and boiler plant for The Trumbull Street Pumping Station (Washington, D. C.). Present position, Engineer with Westinghouse, Church, Kerr & Co.

Elected Junior Member, May, 1902.

References: W. W. Churchill, H. R. Kent, Alex. Dow, Jos. P. Sneddon, W. D. Steele, A. W. Smith.

ARTHUR RAYMOND BAYLIS

Arthur Raymond Baylis, care Jacobs & Davies, 128 Broadway, New York City. Born New York City, 1873. Education, home schools and Pratt Institute, 2 years. 1888-1890, engaged in several courses of study, partly in Technical High and partly in architectural schools and shops of Pratt Institute. 1890-1895, tracer and draftsman, M. T. Davidson Steam Pump Works (Brooklyn), on design of steam pumping engines, evaporator and distillers, boilers, etc. 1895-1897, Chief Draftsman M. T. Davidson Steam Pump Works, having considerable experience on steam pumping station, duty trials at Milburn Pumping Station Mt. Prospect Pumping Station (Brooklyn), and Fall River Pumping Station (Fall River, R. I.). 1897-1902, draftsman Henry R. Worthington's Pump Works, on designs of compound and triple expansion pumping engines and other machinery. 1902-1905, with Messrs. Jacobs & Davies as Mechanical Engineer, Draftsman and Inspector in charge of design and construction of hydraulic tunnel shields and other machinery. March, 1905, to date, mechanical assistant engineer for Hudson Company, in charge of design, construction and inspection of hydraulic tunnel shields and temporary power plants for construction of tunnels under Hudson River.

Elected Junior Member, June, 1905.

References: Jno. D. Logan, F. J. Logan, W. J. Logan, F. F. Nickel, G. I. Bouton, F. E. Idell.

LOUIS L. BRINSMADE

Louis L. Brinsmade, care of Westinghouse Machine Co., 10 Bridge St., N. Y. City. Born Elmira, N. Y., 1875. Education, High School (St. Louis, Mo.), 5 years Washington University and Cornell University; M.E. Washington University, 1896; M.M.E., Cornell, 1897. Drawing-room, (St. Louis) Water Department, Bell Telephone Co., Westinghouse, Church, Kerr & Co. Shop experience, Mo. Car Ry. Co. Six years' experience in engineering work with Westinghouse, Church, Kerr & Co. Management of sales and construction of the New York office of the Westinghouse Machine Co. Present position, Manager New York Office Westinghouse Machine Co.

References: W. R. Roney, H. R. Kent, Wm. W. Churchill, H. D. Watson, Arthur West.

JAMES M. BROWN

James M. Brown, 50 Baldwin Ave., Mansfield, Ohio. Born, Massillon, Ohio, 1873. Preparatory, Kenyon Military Academy and Williams College. S.B., Mass. Inst. Technology, 1897. Seven years with the Aultman & Taylor Machinery Co., in water tube boiler department. Five years assistant to Superintendent. At

present with Stirling Cons. Boiler Co., the latter having purchased the business of the Water Tube Boiler Co., A. & T. M. Co. In charge of the shipping and erecting departments of the Stirling Company (Mansfield Works), which position entails the handling of a large force of men and direct responsibility for progress of contracts from time order enters the shops until finally installed at purchaser's plant.

Elected Junior Member, December, 1900.

References: Alex. E. Brown, Herbert A. Croxton, W. C. Temple, Jas. P. Sneddon, J. Rowland Brown.

HORACE HARCOURT DIXON

Horace Harcourt Dixon, 169 South Canal Street, Chicago, Ill. Born England, 1876. Apprentice, Geo. E. Dixon & Co. (Chicago), 1893-1894. Drawing-room, same firm under personal instruction of the late George E. Dixon, designing apparatus, 1894-1899. In designing, work has consisted in taking off quantities from plans (or from buildings), for estimate and design of. Making plans of buildings, also alterations for old plants to bring same up to modern methods of construction. Superintended installation of complete heating and ventilating apparatus in large office and factory buildings in Philadelphia and Chicago. Past two years given principally to designing apparatus. Partner in firm of Geo. E. Dixon & Company (Chicago and Philadelphia).

Elected Junior Member, December, 1904.

References: A. Sorge, Jr., Jno. M. Sweeney, H.A. Croxton, A. J. Hewlings, C. G. Ludlow, Fred'k Sargent.

GEORGE FREDERICK HIGGINS

George Frederick Higgins, 6 Forest Ave., Worcester, Mass. Born Manchester, N. H., 1862. B.S., Worcester Polytechnic Institute, 1885. Apprentice at machine shops of Amoskeag Mfg. Co., in foundry machine shops and power plant. Drawing-room, Amoskeag Mfg. Co., mill construction, engine and boiler designing, water power installation. 1885-1889, Asst. M.E. Amoskeag Mfg. Co. 1889, Mechanical Expert Nibbs Patent Valve suit versus City of New York. 1890-1893, Consulting Engineer and Contracting Engineer. 1893-1895, Consulting Engineer Winchester Tannery Co. 1895-1900, Consulting Engineer and Treasurer Allen-Higgins Paper Co., designing and installing entire plant. 1900-1906, Consulting Mechanical Engineer.

Elected Junior Member, May, 1886.

References: Chas. H. Manning, Milton P. Higgins, Geo. I. Alden, Stephen W. Baldwin, V. E. Edwards.

ELMER KIRKPATRICK HILES

Elmer Kirkpatrick Hiles, 2 Cottage Place, Warren, Pa. Born Chicago, Ill., 1870. B.S., University of Illinois, 1895. Apprentice, C. A. Hiles Co. (Chicago), 1887-1890. Shop experience, Ball & Wood (Elizabeth), 1895; erecting engineer with same company, 1895-1897. Engineer Chicago City pumping station, 1897. Westinghouse, Church, Kerr & Co., power house installation, 1898. Assistant engineer and chief draftsman, Osborne Pipe Line System, 1899-1901. 1901-1903 with Chas. E. Sargent, engaged in perfecting, developing and putting on a commercial basis the Sargent gas engine. 1903-1906, with Westinghouse Machine Co., designing gas engines, in charge of installation of large gas engine plants, and 1905-1906, engaged in design of 3500 H. P. blowing gas engine, being responsible

for final O. K. on all drawings for the engine. Present, Chief Engineer, engaged in design and construction of gas engines, Struthers-Wells Co.

Elected Junior Member, November, 1900.

References: Arthur West, E. S. McClelland, Wm. A. Bole, H. L. Barton, Chas. E. Sargent, Wm. L. Abbott.

EMANUEL HOLLANDER

Emanuel Hollander, Chief of Estimating Staff, Engrg. Dept., Otis Elevator Co., 17 Battery Place, N. Y. City. Born New York City, 1875. Seven years public schools; three years Evening High School; five years at Cooper Union; part term at Pratt Institute; two years post-graduate Cooper Union, degree of B.S., 1896; M. E., Cooper Union, 1902. 1890-1901, elevator and hoisting machinery, laying out, calculating, designing elevator plants (electric, steam and hydraulic), Otis Elevator Co. Five years experience estimating elevator work and engineering construction. In charge of work one year. Now holds position of Chief of Estimating Staff, Engineering Department

References: John Griffith, Reginald Pelham Bolton, George B. Caldwell, B. S. Harrison, S. D. Collett, William Schwanhausser.

GEORGE LEWIS HOLMES

George Lewis Holmes, 140 Santa Clara Ave., Oakland, California. Born Lockport, N. Y., 1871. Drawing-room, 1887-1895, Holly Mfg. Co., one year Assistant Foreman of foundry. With Lake Erie Engineering Works (Buffalo), 1895-1896. Mackintosh & Hemphill (Pittsburg), and one year with E. P. Allis Co. One year Bucyrus Co. (S. Milwaukee), and American Glucose Sugar Co. during construction of plant. One year Chief Engineer of Folsom Development Co. (Folsom, Cal.), then entered practice of Consulting Engineer which is present position.

Elected Junior Member, December, 1899.

References: Staunton B. Peck, Jno. V. Schaefer, W. S. Noyes, James M. Dodge, Chas. Piez, A. W. Robinson.

RICHARD ADDISON SMART

Richard Addison Smart, Asst. Supt. Westinghouse Elec. & Mfg. Co., E. Pittsburg., Pa. Born Ft. Wayne, Ind., 1872. Common and private schools. M.E., Purdue University, 1894. Instructor in engineering laboratory and Associate Professor of Experimental Engineering, 1892-1901. Consulting Engineer with National Malleable Castings Co., for a short time. Experimental Engineer, B. F. Sturtevant Co.,1901-1903, in charge of experimental work and steam engine design. 1903-1905, with Westinghouse Elec. & Mfg. Co. as assistant to superintendent of production. Author "Hand-book of Engineering Laboratory." Present position, assistant superintendent in charge of all matters relating to rate of production and delivery; in charge of shop system and clerical force.

Elected Associate Member, June, 1900.

References: Edwin M. Herr, W. F. M. Goss, Geo. M. Basford, G. R. Henderson, Walter B. Snow.

TO BE VOTED FOR AS ASSOCIATES

LESLIE DOUGLASS ANDERSON

LESLIE DOUGLASS ANDERSON, Engineer in charge Arizona Smelting Co., Humboldt, Yavapai Co., Arizona. Born Michigan, 1879. Four years High School, Ishpeming, Mich; 1897-1901, University of Michigan, B. S., April, 1901. Apprentice, Nordberg Mfg. Co. (Milwaukee), three months; 1901-1902, drawing-room, Nordberg Mfg. Co. (Milwaukee); 1902-1903, Bucyrus Company (So. Milwaukee), and 1904-1905, mechanical engineer Champion Copper Co. (Painesdale, Mich.); August, 1905-February, 1906, M. E. Arizona Smelting Co., placed in full charge, of all engineering and construction work. Present position, Engineer in Charge, Arizona Smelting Company.

References: John. R. Allen, S. L. G. Knox, R. H. Corbett, O. P. Hood, Cyrus Robinson.

ALFRED EDWARD BALLIN

ALFRED EDWARD BALLIN, Buffalo, N. Y. Born Natchez, Miss., 1879. Education, 2 years college tutoring with F. L. Wilson, M. E. in technical and experimental lines. Apprentice, The Snow Steam Pump Works, 1899, general detailing and designing. Was general engine man in drawing-room, designing water works, pumping and large unit gas engines and in planning installations for the Snow Steam Pump Works. Considerable shop experience in connection with outside installations of pumping machinery and gas engines. Further, conducted tests of many large water works pumping engines. General charge of erection of several water works engines and large unit gas engines and considerable experience in operating same. Was assistant chief draftsman prior to holding present position. Present position, Ass't Chief Engineer Snow Steam Pump Works.

References: Elgood C. Lufkin, Clarence N. Scott, Walter Laidlaw, S. B. Daugherty, E. C. Sornborger.

JOHN J. BOYD

JOHN J. BOYD, President Hudson Eng'g and Contracting Co., 92 William St., New York City. Born New York City, 1870. Six years Columbia grammar school. 1891-1899, associated with Cornell, Hiscox & Underhill in charge of designing and erecting high pressure steam piping and water supply plants. 1899-1904, with Bacon Air Lift Company. 1904 to present time, with the Hudson Engineering and Contracting Company, designing, locating and installing water works and pumping plants. Present position, President Hudson Engineering and Contracting Company.

References: Robt. M. Anderson, Louis R. Alberger, E. H. Foster, J. E. Denton, H. W. York, F. L. DuBosque.

ABEL DELANCY CATLIN

ABEL DELANCY CATLIN, President Chattanooga Machinery Co., Chattanooga, Tenn. Born Schuyler County, New York, 1848. Apprentice Silsby Mfg. Co. (Seneca Falls, N. Y.) for nine years, tool making and foreman of department, general drawing and designing. Shop experience with Silsby Mfg. Co., and three years and a-half with Smalley Bros. & Co. (Bay City, Mich.); five and one-half years Treasurer and General Manager of Standard Machinery Co. (Bay City, Mich). For eighteen and one-half years connected with present company, now

President and General Manager, engaged in designing and building special wood and iron working machinery, including Catlin keyseater and cross arm and insulator pin machinery.

References: Newell Sanders, F. R. Hutton.

CHARLES WARREN COMSTOCK

Charles Warren Comstock, The Wellman, Seaver, Morgan Co, Cleveland, Ohio. Born Cleveland, O., 1872. Graduated Brooks Military Academy; Cleveland, O., and Cleveland Manual Training School. From July, 1890 to July, 1892, with A. M. Smith, Architect, Cleveland, O. From Aug., 1892 to May, 1893, The Yale & Towne Mfg. Co., Philadelphia office; June, 1893 to Dec., 31, 1896, Architect in own business in Cleveland, O.; Jan. 1, 1897, with the Wellman, Seaver, Morgan Co.; Cleveland O , with the title of Purchasing Agent. In charge all purchases and inspection of all material purchased until the completion of the W. S. M. Co.'s plant 1903, all machinery, etc., required by them in executing their contracts (principally rolling mill and open hearth plants) was purchased outside. Supervision and inspection of all material used and work done during construction, and final inspection of all completed machines. Since completion of plant in Cleveland, and later plant at Akron, O., in charge of all purchase of all plants. Holds position of Purchasing Agent, The Wellman, Seaver, Morgan Co., Purchasing Agent for the above Company, ten years on Jan. 1, 1907.

References: A. Swasey, Geo. Bartol, Jno. McGeorge, M. Reid, H. H. Hill, H. B. Brather, S. T. Wellman, S. H. Pitkin.

GEORGE W. CORBIN

George W. Corbin, President, Corbin Cabinet Lock Co., New Britain, Conn. Born New Britain, Conn., 1859. President Corbin Cabinet Lock Co.

References: Robt. S. Brown, Howard S. Hart, C. M. Jarvis, Lewis C. Grover, Chas. E. Billings.

PHILIP GRENVILLE DARLING

Philip Grenville Darling, 23 Watson St., Boston, Mass. Born Somerville, Mass., 1878. Four years Harvard University; four years at Hotchkiss School. Three years Mass. Institute Technology, S.B., 1905; A.B., Harvard, 1901. 1903-1905, irregular work with W. M. Wheeldon (Boston), drafting. Sept., 1906, to present time, with United Injector Co., for Manning, Maxwell & Moore. June-October, 1904, Amoskeag Mills (Manchester). July-Sept., 1899-1900, Metropolitan Sewerage Commission of Boston. Series of tests upon a Curtis turbine for the Nashua Heat, Light and Power Co. (Nashua, N. H.), as thesis work. Designed and conducted original experiments upon the pressure drop in valves and piping, for the Hancock Inspirator Co. (Boston). Boiler installation and engine running with Amoskeag Mills. For the Metropolitan Sewerage Commission, rodman, transitman and in charge of leveling party. Present position, Mechanical Engineer with Manning, Maxwell & Moore, engaged in steam testing.

References: Edw. F. Miller, Peter Schwamb, Gaetano Lanza, Chas. H. Manning, B. T. Williston.

CHARLES ALBERT FRANCIS

Charles Albert Francis, The Higher Technological School, Tokio, Japan. Born Mansfield, Mass., 1866. Apprentice, Mansfield Watch Tool Co. (Mass.),

Machinist L. L. Pollands, 1884-1888. Machinist T. & H. Electric Co. (Lynn), April-August, 1888. Tool and model maker L. L. Pollands (Worcester), 1888-1890. Mechanician, department of physics, Clark University (Worcester), May, 1890-January, 1894. Mechanician, department of physics, University of Chicago, 1894-1898, and June, 1898-August, 1899. Tool maker Veeder Mfg. Co. (Hartford), August-December, 1899. Special mechanician Yerkes Observatory (Wisconsin), December, 1899-June, 1900. Foreman direct meter dept. Diamond Meter Co. (Peoria, Ill.), June, 1900-March, 1901. Pratt & Whitney Co. (Hartford), 1901-1903. Master mechanic and lecturer before graduating class, department of mechanical engineering, Tokyo Koto Kogyo Gakko, 1903-1906. Secretary Oriental Engineering Society, June, 1904, to date. Assistant instructor physical manipulation, summer class of 1897-1898, under Prof. S. W. Stratton. Assisted G. Cook and J. H. Wooly of Chicago in getting up instruments for the application of heating dentistry for the destruction of pathogenic germs, 1898. At present Instructor and Master Mechanic The Higher Technological School (Tokyo).

References: Francis C. Pratt, B. W. Hanson, W. N. Parsons, Edw. Rivett, S. Sakata.

CLAUDE MALLORY GARLAND

Claude Mallory Garland, Instructor in Mechanical Eng'g, University of Illinois, Urbana, Ill. Born Kentucky, 1880. B.E., Engineering Department, Vanderbilt University, 1903. Drawing-room, Union Electric Light and Power Co., March-November, 1904. Shop experience, Bullock Electric Co. (Cincinnati), June, 1903-January, 1904; American Brake Co. (St. Louis), January-March, 1904. Engineer with Mutual Light and Heat Co. and Diamond Ice & S. Co., Dec.-June, 1904-1905; Cutler Hammer Electric Co., June-September, 1905. September, 1905 to date, Instructor in Mechanical Engineering, University of Illinois.

References: C. S. Brown, M. L. Holman, D. T. Randall, L. P. Breckenridge, T. M. Gardner.

LEONARD GOODWIN

Leonard Goodwin, 8 Oliver St., Boston, Mass. Born So. Bethlehem, Pa., 1871. Shop experience, Lehigh Valley Railroad Southeastern, Pa.). Connected with the mechanical and civil engineering department of the L. V. R. R., also transportation department; for one year general superintendent Lehigh & New England R. R. Resigned from railroad work to become President and General Manager of the Contractor's Plant Company (Boston) in July, 1902, since which time been engaged principally in designing, manufacturing and erecting plants for contractors, more especially concrete mixing plants. Present position, General Manager of Contractor's Plant Co. (Boston).

References: Frank B. Gilbreth, W. H. Larkin, Jr., Walter B. Warren, Jno. Fritz, Albert Ladd Colby.

WILLIAM HENRY HARMAN

William Henry Harman, Mechanical Engineer, Engineers' Club of Philadelphia. Born at Camden, N. J., 1879. Four years Camden High School. Apprentice Camden Iron Works, 1896. During this time in drawing-office. Since 1903, in charge of department, building hydraulic tools, Camden Iron Works.

References: H. V. Willie, A. A. Stevenson, William S. Bidle, Fred V. Matton, P. W. Power.

CHARLES PARKER HOLT

CHARLES PARKER HOLT, Vice-President, Holt Mfg. Co., Oakland, Calif., 1880. B. S., University of California; B. S., Cornell University, 1903. Apprentice, Holt Mfg. Co. (Stockton), pipe fitting, machine and Holt Mfg. Co. erecting shops, 1900-, 1903 (during college vacations). Drawing-room, at various times on special work Holt Mfg. Co. Shop experience Houser & Haines Mfg. Co., Holt Mfg., Co., January 1904-March 1905. Other practical experience; foreman boiler shop, engineer on traction engine in field, etc.; buying and inspecting material in middle and eastern states; in charge of boiler department, both design and construction; and cost keeping in shops. Present position, Vice-President, Holt Manufacturing Co.

References: W. A. Doble, F. L. Norton, C. E. Newton, L. K. Malvern, M. L. Libby.

WILLIAM ROWSELL HULBERT

WILLIAM ROWSELL HULBERT, Managing Editor, "Compressed Air," 90 West Broadway, New York City, Born Brooklyn, N. Y., 1880. Six years Columbia grammar school (New York City), 6 years Pratt Institute; Ohio State University, Columbia University; M. E., Columbia University; 1904. Power and Mining Machinery Co. (Cudahy, Wis.), August-October, 1904. In charge of electrical installation Department of Varied Industries, Paris Exposition, 1900. October, 1904-March, 1905, engineer at shops of Rand Drill Co. (Tarrytown, N. Y.), most of time in testing pneumatic tools and appliances. March-August, 1905, acted as Assistant to Sales Manager New York office, Rand Drill Co. August, 1905, to date, Secretary the Kobbe Company. Present position, Managing Editor "Compressed Air" and Secretary the Kobbe Company.

References: Chas. A. Moore, Chas. E. Lucke, H. V. Conrad, S. S. Jordan, F. O. Willhofft.

WILBUR GOODSPEED LAIRD

WILBUR GOODSPEED LAIRD, Chief Engr. Improved Equipment Co., 728 Tenth Ave., Denver, Colo. Born Canton, Ohio, 1878. Grammar and High School. Apprentice, Denver Eng'g Works (Denver, Colo.), machine design and estimating. February, 1898-June, 1902, design and development of mining, milling and smelting machinery. Drawing-room, Geo. A. Laird, Superintendent La Victoria y Anexas, San Pedro, S. L. P. (Mexico), 1902. Denver Eng'g Works, 1902-1903, in charge machine design. 1903, Mine and Smelter Supply Co. (Denver). Improved Equipment Co., 1903-1906. While in Mexico mine and surface surveying. Considerable experience in development of patents. Full charge of gas bench design and personal superintendence of practical installation of these plants. Present position, Chief Engineer Improved Equipment Co., design of gas plants and detail.

References: Frank E. Shepard, Lewis Searing, Henry L. Doherty, H. C. Abell, Harry A. Deuel.

JOHN LEEFE SHEPPARD, JR.,

JOHN LEEFE SHEPPARD, JR., 222 Chestnut Street, Harrisburg, Pa. Born Charleston, S. Carolina, 1874. M. E., Lehigh University, 1897; Apprentice, general machine shop work with Georgia Iron Works (Augusta, Ga.), and General Electric Co. (Schenectady), electric and steam machine testing. First six months; 2d Jany., 1903-December, 1904. Drawing-room, Georgia Iron Works, Valk & Murdock Iron Works (Charleston, S. C.), Whaley & Co. (Columbia, S. C.), J. E. Serring (Greenville, S. C.), Platt Iron (Dayton, O.), for about five years with above

concerns. 1899-1901, in charge of the reconstruction of track work of Columbia Electric Street Ry. (Columbia, S. C.), construction and testing of several cotton mill power plants, also general mechanical engineering work, water-power surveys, reports, etc. 1902, Resident Engineer (Anderson and Greenville, S. C.), reconstruction of Portman dam, Anderson W. L. & P. Co. Plans and specifications lighting and power for cotton mills, J. E. Serring (Dayton, O.) Designed water wheels Tuolumne Elec. Co. (Cal.), 75 H. P. Shoshone Falls P. Co. (Cal.), 850 H. P. Ell River P and Trig. Co. (Cal.) 4000 H. P. and numerous other high and low head wheels. At present Mechl. Engr. and Draftsman engaged in design of power plant for central Penn. Trac. Co. (Harrisburg), Mason D. Pratt.

References: J. F. Klein, Strickland L. Kneass, T. J. Bray, Jr., Jno. O. DeWolf, G. A. Buvinger.

HOWARD ELLSWORTH TROUTMAN

Howard Ellsworth Troutman, Atlas Engine Works, Indianapolis, Ind. Born Creston, Ohio, 1868. Drawing-room, laying out and advising in construction of steam plants and adapting machinery to various conditions, with A. G. Harmes and the Buckeye Engine Co. With Buckeye Engine Co. (Salem, O.), manager of branch office in Pittsburg, Boston, and Chicago, from 1893-1906. Present position, since February, 1906, Manager of Sales for Corliss and high speed engines, Atlas Engine Works.

References: C. H. Weeks, A. K. Mansfield, Geo. M. Brill, A. Sorge, Jr., Jno. R. Whittemore.

CARL OTTO TRUELL

Carl Otto Truell, 71 Broadway, New Jersey Zinc Co., N. Y. Born Nashua, N. H., 1878. Four years Nashua (N. H.) High School; four years Worcester Polytechnic Institute, S. B. June, 1901. June, 1901 to April, 1902; Morgan Construction Co.; (Worcester, Mass.); continuous rolling mills and general mill work. April, 1902 to Sept., 1902, Lyman Mills, (Holyoke, Mass.); Sept., 1902 to Jan., 1905, Pump Dept. the Allentown Rolling Mills, (Allentown, Pa). Jan., 1905 to Sept., 1905, Cambria Steel Co. (Johnston, Pa.); Sept., 1905 to Dec., 1905, Republic Iron & Steel Co. (Youngstown, O.); Dec., 1905 to August, 1906, Steel Mill Dept. Milliken Bros., N. Y., Engineers and Contractors. With Lyman Mills acted as Asst. to Master Mechanic, having general inspection of power equipment and machinery. With Allentown Rolling Mills, Assistant to Chief Engineer; figured estimates original pump designs, tested pumps and attended to pump department correspondence. With Cambria Steel, Republic Iron & Steel and Miliken Bros., had large amount of outside engineering work in connection with drafting work. Present position, with New Jersey Zinc Co., consists chiefly of inspection of material. Present position, of inspector and draftsman, N. J. Zinc Co.

References: H. Fairfield, A. Kingsbury, S. A. Reeve, A. L. Smith, H. G Harrington, C. M. Allen.

FOR PROMOTION TO ASSOCIATES' GRADE

HOLSTEIN DE HAVEN BRIGHT

Holstein De Haven Bright, 1608 Summer St., Philadelphia, Pa. Born Pennsylvania, 1880. Two years Spring Garden Institute; one year Drexel Institute. Apprentice, Baldwin Locomotive Works, Burnham, Williams & Co., 1899-1901,

drawing-room work on general machine and repair work. Shop experience, Baldwin Locomotive Works on general repairs, buildings and construction work, 1899-1902. April 1, 1901-Jan., 1902, Assistant Foreman of repairs and maintenance, Baldwin Locomotive Works. Jan. 1902-1904, Foreman of general repairs and construction. Jan., 1904-April, 1905, Assistant to Mr. S. M. Vauclain, in charge general mechanical maintenance and repairs. Present position, Manager, Spring Department, Baldwin Locomotive Works and Standard Steel Works.

Elected Junior Member, December, 1905.

References: S. M. Vauclain, H. V. Wille, L. H. Fry, A. A. Stevenson, Wm. Burnham.

MORRIS ALBERT HALL

Morris Albert Hall, Lock Box 103, Three Rivers, Mich. Born Buffalo, N. Y., 1880. B. S. in M. E. University of Michigan, 1904. Apprentice, Geo. A. Ricker, C. E., Buffalo, N. Y., as rodman, chainman, leveler, transit man and draftsman 1899-1900. Drawing-room, A. E. Baxter, M. E., Buffalo, N. Y. on power plant design and appraisal for 1 year. In charge of office of F. A. Shoemaker, M. E., Buffalo, N. Y., on power plant design, construction and inspection 3 months. Steam engine designing with Buffalo Forge Co., 3 months. Shop experience, Wagner Palace Car Co., Buffalo, N. Y.; wood working department; 1 year also Whitehead & Kales Iron Works, Detroit, Mich. on structural iron work as machinist, assembler, layerout and foreman. Further, designer with Iroquois Iron Works on concrete mixers, road and macadam rollers, commercial vehicles 3 months; chief draftsman Mack Bros. Motor Car Co., Allentown, Pa, 1 year, chief draftsman motor car dept., Sheffield Car Co., Three Rivers, Mich.; 1 year Independent designer automobile gasolene engines.

Elected Junior Member, 1905.

References: C. H. Morse, Jr., M. E. Cooley, John R. Allen, W. Grant King, C. H. Bierbaum.

MILTON WARD HOGLE

Milton Ward Hogle, 1065 Frick Bldg. Annex, Pittsburg, Pa. Born Lawrence, Mass., 1878. Three years Rochester Free Academy; 1 year University of Rochester; 2 years Mass. Institute Technology, S.B., 1901. July-November, 1901, Eastman Kodak Co., Const. Dept. (Rochester), machine design and boiler tests. 1901-Aug., 1902, American Sheet Steel Co. (Wellsville, O.), first five months on repair gang, remainder of time assistant to master mechanic, laying out and overseeing engine and building foundations, erecting machinery and furnaces. Aug., 1902-Dec., 1905, with Engineering Department American Sheet and Tin Plate Co. under S. B. Ely, chief engineer, as draftsman and engineer on surveying corps; later as general utility man under chief engineer in charge of tests and taking up various engineering problems with managers of 36 various plants. Present position, Acting Chief Engineer for P. E. Donner in design of new steel plant.

Elected Junior Member, December, 1901.

References: Sumner B. Ely, Daniel Ashworth, R. R. Goodrich, Peter Schwamb, Gaetano Lanza.

REDFIELD PROCTOR, Jr.

Redfield Proctor, Jr., Asst. Supt. Vermont Marble Co., Proctor, Vt. Born Proctor, Vt., 1879. Three years Friends School (Washington, D. C.); three years Mass. Institute Technology. During summer vacations electrician and rodman,

also transitman. Sept., 1902, entered employ of Vermont Marble Co., as assistant engineer in charge of testing all coals and oils and inspection and repair of boilers and water wheels; also charge of 500 H. P. electric power station. 1903, appointed superintendent of power department, having charge of generation and transmission of all power for the three large plants of Vermont Marble Co., at Proctor, West End Center, Rutland, including water, steam and electric power, economic distribution of same and supervision over all installations and repairs. Have direct and entire charge of a large stone crushing plant, also supplying sand used at eleven of the company's plants in Vermont, including the pit, two mines of conveyors and all railroad transportation of same; three locomotive cranes, shipment of all rough stock orders; in charge of over 100 men. Present position, Assistant Superintendent, main plant Vermont Marble Company.

Elected Junior Member, June, 1905.

References: Peter Schwamb, Walter Humphreys, Edward Robinson, A. B. Tenney, E. F. Miller, K. F. Wood.

TO BE VOTED FOR AS JUNIORS

CECIL F. ADAMSON

Cecil F. Adamson, Hamilton Bldg., Akron, Ohio. Born Carlton, Ohio., 1882. Ordinary home and high schools. Apprentice (Akron, O.), Alex. Adamson, Machine Co., Pittsburg Machine Tool Co., Chicago Pneumatic Tool Co., 1896-1902. Shop experience, Alex. Adamson, 1902-1903. While in Pittsburg engaged principally in machine tool designing, then in charge of construction of the shops which now belong to Chicago Pneumatic Tool Co. (Franklin, Pa.). From 1891-1893, in Engineering Department, Carnegie Steel Co. (Ohio Works). Past three years devoted to general engineering practice at Akron, Ohio, as Mechanical and Electrical Engineer.

References: F. B. Cowan, C. J. Carew, J. S. Lane.

WALTER ALDRICH BARRETT

Walter Aldrich Barrett, Chief Draftsman, Bass Fdy. and Mach. Co., 2325 Fairfield Ave., Fort Wayne, Ind. Born Ft. Wayne, Ind., 1883. B. S. in M.E., University of Michigan, 1904. Apprentice, Bass Foundry and Machine Co., 1904-1905, general machine shop work. Drawing-room, 1905-1906, to date, in office of Bass Foundry and Machine Co. For past four years looked after all drawing-room work and design under supervision of mechanical superintendent and engineer. Present position, Chief Draftsman, Bass Fdy. and Machine Co.

References: Geo. T. Ladd, H. J. Horstmann, Wm. S. Morris.

ORVILLE GREEN BENNET, Jr.

Orville Green Bennet, Jr., 45 West 84th St., New York City. Born New York City, N. Y., 1881. M. E., Cornell University, 1904. Six months after graduation with Westinghouse, Church, Kerr & Co. in department of engineering estimates under A. V. Abbott. Since 1905 with Ingersoll-Sergeant Drill Co. Present position, assistant electrical engineer, work consisting mainly in laying out and estimating for electrically driven air compressor units. Under contract to go to Japan for American Trading Company in general machinery business.

References: H. V. Conrad, H. T. Abrams, F. W. Parsons, R. C. Carpenter.

RICHARD CARTER BEVERLEY

Richard Carter Beverley, 621 East Franklin Street, Richmond, Va. Born Virginia, 1881. Four years Virginia Polytechnic Institute, B.S., 1900. Asst. Manager Mechanical Department, Smith Courtney Co. (Richmond, Va.), from Feb., 1901, to March, 1903; previous to that time in office of L. S. Randolph, Consulting Engineer, assisting in design, estimating and construction of power plants, both hydraulic and electric, also heating and ventilating work of all kinds, together with factory work, such as tobacco, cotton machinery, etc. Present position, Manager of Mechanical Department, Smith Courtney Co.

References: T. S. Randolph, Edw. J. Willis, Edgar C. Wiley, H. S. Morrison, B. H. Cameron.

WALTER J. BITTERLICH

Walter J. Bitterlich, 33 Dexter Ave., Watertown, Mass. Born Bridgeport, Conn., 1880. Boardman Training School (New Haven), grammar school and private tuition. Apprentice, Sargent & Co. Hdw. Mfg., drafting department, 1899-1903, in following positions: 1st year, general office work in charge of patterns; 2d year, tracing and simple drawing; 3d year, detail and assembly, and design of special machinery 4th year. Shop experience, Hood Rubber Co. (Watertown, Mass.), some pattern making and experimental and model making on special machine. 1905-1906, Chief Draftsman Hood Rubber Co., also experience in outside engineering, developing general layouts, power, piping and power transmission. In charge of mechanical department in absence of master mechanic. Present position, Chief Draftsman Hood Rubber Company.

References: E. W. Day, H. B. Sargent, R. MacArthur, Jr.

GEORGE STEVENS BLANKENHORN

George Stevens Blankenhorn, 672 Astor St., Milwaukee, Wis. Born Milwaukee, Wis., 1883. Four years at Throop Polytechnic Institute, Pasadena, Cal.; three years at Cornell and University of Wisconsin. Drawing-room, designing gas-engine parts, and plans for irrigation pumping plants. (Western Gas-Engine Co., Los Angeles Cal., March to Sept., 1905. Two summers during school vacation with Hodge Bros., Pasadena, Cal., doing all kinds of erecting and machine work. Charge of machine shop at Solar Observatory on Mt. Wilson, Cal., installing gas-engine plant, setting up two telescopes, and the instruments and machine work generally, December to March, 1904-1905. Three months of summer vacation for Pasadena & Los Angeles Elect. Ry., power-house, in boiler and engine room; Los Angeles Steam Engineers' License, and U. S. Marine Gas Engineer's License. Present position, Allis Chalmers Co., Milwaukee, Steam turbine work.

References: Storm Bull, J. G. D. Mack, Murray C. Beebe.

JOSEPH ALDRICH BURSLEY

Joseph Aldrich Bursley, 2515 Fairfield Ave., Fort Wayne, Ind. Born Fort Wayne, Mich., 1877. Three years University of Michigan; one year Cornell. B. S. (M.E.), University of Michigan, 1899. Apprentice, Pennsylvania Company (Ft. Wayne, Ind.), Sept., 1899-June, 1902, tests of various kinds and in shops. Since February, 1904, Instructor in Mechanical Engineering, University of Michigan, which is present position.

References: M. E. Cooley, J. R. Allen, J. G. Aldrich, Geo. L. Wall, D. F. Crawford.

LEONARD THEAKER BUSHNELL

LEONARD THEAKER BUSHNELL, 83 Newbury St., Boston, Mass. Born New Bedford, Mass., 1880. B. A. Yale, 1902. S. B. Mass. Inst. of Technology, 1905.
References: Gaetano Lanza, Edward F. Miller, H. L. Coburn.

WILLIAM LYLE CATLIN

WILLIAM LYLE CATLIN, Supt. Chattanooga Machinery Co., Chattanooga, Tenn. Born Seneca Falls, N. Y., 1875. Four years Grant University; four years Cornell, M. E., 1900. 1894-1898, apprentice Chattanooga Machinery Co., machine shop and drafting room; drawing-room and shop experience same time; for five years in charge of machine shop, manufacturing and building special and standard saw mill and wood working machinery, general charge of the drafting-room. Present position, Superintendent of Chattanooga Machinery Co.
References: Newell Sanders, D. S. Kimball, F. R. Hutton.

ALBERT EDWARD COLEMAN

ALBERT EDWARD COLEMAN, Pratt & Whitney Company, Hartford, Conn. Born Ilion, N. Y., 1876. Apprentice, (Hartford, Conn.) Pratt & Whitney Co., machinist and tool making Sept., 1897-May, 1900. Drawing-room, May, 1900-June, 1901. Five months with Russell & Erwin's drawing-room (New Britain, Conn.); also did all drawing for Phoenix Iron Works (Hartford). Returned to Pratt & Whitney Co., designing jigs and fixtures, having charge for two years, then designing machines for a year. Since September, 1905, superintendent construction of new buildings for Pratt & Whitney Co. Taught mechanical drawing in Hartford Public Evening Schools for three years during the winter months. Present position, Plant Engineer Pratt & Whitney.
References: B. M. W. Hanson, Francis C. Pratt, Wm. N. Parsons.

JOHN PUTNAM COOK

JOHN PUTNAM COOK, 2011 Lexington Ave., New York City. Born Athol, Mass., 1880. B. S. in M. E., Purdue University, 1902. N. Y. C. & H. R. R. Co., as special apprentice, general railroad work, Aug., 1902-April, 1905. Drawing room N. Y. C. & H. R. R. Co. April, 1905, to date. Shop experience, same time. N. Y. Central R. R. representative at St. Louis on P. R. R. testing plant for four months. Present position, draftsman engaged in general locomotive and railroad work.
References: W. F. M. Goss, F. M. Whyte, C. H. Quereau.

J. EDMONDS FORGY

J. EDMONDS FORGY, 1½ Central Ave., Ithaca, N. Y. Born Dayton, Ohio, 1883. M. E., Sibley College, Cornell University, 1906. Apprentice, E. I. DuPont Company (Wilmington), operating department, beginning July, 1906, on testing and installation of power plants. Present engaged in power installation work.
References: A. W. Smith, D. S. Kimball, R. C. Carpenter.

ARTHUR GEORGE FRECHTLING

ARTHUR GEORGE FRECHTLING, care Fairbanks, Morse & Co., Cincinnati, Ohio. Born Hamilton, Ohio, 1879. M. E. Ohio State University, 1901. Apprentice,

Union Pacific R. R. substitute at Omaha, Denver & Cheyenne, also Fairbank, Morse Mfg. Co.; at Beliot, Wis., 1901-1903 and 1905-1906. Car work, round house and road work and office work with U. P. R. R. Shop work on gas engines with F. M. Co. Drawing-room, U. P. R. R., about six months of designing and experimenting. Shop experience, about 18 months with former and 12 months with latter, manufacturing gas engines, erecting, testing and foundry work. Fifteen months, 1903-1905, with Mr. Harrington Emerson as assistant in putting in new shop methods at Portland, Maine. Three months with U. P. R. R., winter 1902-1903, taking care of car-heating as traveling inspector. Three months as assistant to F. N. Hibbits, Mechanical Engineer U. P. R. R., designing and experimenting with new locomotive appliances and shop methods. Present, traveling salesman, Fairbank-Morse & Co.

References: W. T. Magruder, E. A. Hitchcock, Harrington Emerson, A. T. Bruegel, J. D. Bird.

ROBERT PETER FRITCH

Robert Peter Fritch, Wilkins and Dunmoyle Aves., Pittsburg, Pa. Born Reading, Pa., 1883. M. E., Sibley College, Cornell University, 1905. Drawing-room, Heyl & Patterson (Pittsburg), July-October, 1905. Shop experience, P. & R. locomotive shops, July-October, 1902. Present position, Concrete Engineer engaged in reinforced concrete building with Expanded Metal Co. (Pittsburg).

References: Albert W. Smith, R. C. Carpenter, Dexter S. Kimball.

EDWARD FRANCIS GAVAGAN

Edward Francis Gavagan, 299 Broadway, New York City. Born Boston, Mass., 1878. Two years' course in engineering and electricity, Mass. Nautical Training School. Drawing-room at school, Sept., 1893-April, 1894, and Oct., 1894-April, 1895. Shop experience, same time. Engineer Cadet U. S. S. "St. Paul," nine months, then Junior Engineer until December, 1898. Had full charge of 60 ton refrigerating machinery and main engine room, experience including boiler, pumping and electrical gear. April-October, 1898, chief machinist U. S. N. Jan-December, 1899, assistant engineer Edison Electric Illg. Co. (Boston) and erecting McIntosh and Seymour engines, and general electrical machinery. February 15, 1901-Oct., 1902, first assistant engineer rope walk power plant U. S. N. Yard (Boston). Appointed by special examiner of U. S. Civil Service as mechanical, engineer and detailed to Philadelphia; resigned Sept., 1903. Present position M. E. and representative in New York City, engaged in special design of furnace work for steel mills, blast furnaces and smokestack layouts.

References: Jno. A. Stevens, Edw. L. Jennings, A. S. Fairbanks.

WM. W. HACKNEY

Wm. W. Hackney, Jr., Fort Wayne, Ind. Born Dayton, Ohio, 1883. 1905, M. E., Ohio State University. 1905, apprentice, producer gas work with Westinghouse Machine Co. Since then in production dept. Western Gas Construction Co. Summer 1903, drawing-room with what is now the Platt Iron Works (Dayton, Ohio). Present position, in charge of production department, Western Gas Construction Co., reporting to Assistant Engineer.

References: W. T. Magruder, E. A. Hitchcock, O. N. Guldlin.

PAUL COLLINS HALDEMAN

PAUL COLLINS HALDEMAN, Speakman Hotel, Coatesville, Pa. Born Westfield, Mass., 1879. B.S., Pennsylvania State College, 1901. Assistant to Master Mechanic Lukens Iron and Steel Co. (Coatesville, Pa.), four years. Draftsman Semet-Solvay (Syracuse), seven months. Present position, Assistant Master Mechanic Lukens Iron & Steel Co.

References: Chas. L. Griffin, H. C. Moyer, L. E. Reber.

FRANZ HERBERT HIRSCHLAND

FRANZ HERBERT HIRSCHLAND, 68 Broad St., New York, N. Y. Born Essen (Ruhr), Germany, 1880. Technical Universities in Hanover and Berlin, Germany. Diploma Ingenieur, 1902., Doctor Ingenieur, 1906. Drawing-room, Union Maschinenbau Actien Gesellschaft (Essen, Germany). Nichols & Langworthy Machine Co. (Hope Valley, R. I.). From Oct., 1904-1905, made experiments with wire ropes to determine the elasticity and the power required for bending wire ropes and also the losses in transmission. Published in Dinglers Polytechniches Journal (Berlin), April and May, 1906. Ueber die Formanderung von Drahtseilen von Hirschland. Present position, draftsman Nichols & Langworthy Machine Co., Hope Valley, R. I.

References: J. Stewart Thomson, Herman Dock, D. S. Jacobus.

THURMAN WELFORD HOLLOWAY

THURMAN WELFORD HOLLOWAY, Scranton, Pa. Born Zanesville, Ohio, 1879. 1904, M. E. Ohio State University. 1902, apprentice, Eastern Tube Works, machine shop, Zanesville, Ohio, working on various machine tools, doing general repair work and tap and die work. Shop experience, O. S. U. machine shop, Columbus, O., during school year, 1902–1903, doing machine work and bench work. Summer of 1903 with Baltimore & Ohio R. R. shops at Zanesville, Ohio, general repair work on engines. Summer of 1904 with Mark Mfg. Co. (successors to Eastern Tube Co.), general machine work and erecting. During school year 1904-1905, was assistant in the department of Mechanical and Experimental Engineering at O. S. U. Present, Asst. Principal of School of Mechanical Engineering, International Correspondence School, Scranton, Pa.

References: A. B. Clemens, W. T. Magruder, E. A. Hitchcock, E. H. Powell.

JOHN JACOB HOWELL

JOHN JACOB HOWELL, 210 West 122d Street, New York City. Born New York City, 1881. Four years Horace Mann High School; 4 years Columbia University, degree of M.E., 1904. In construction and mechanical departments, Westinghouse, Church, Kerr & Co. Experimental testing work on steam turbines. In construction department of A. B. See Electric Elevator Company. Present position, Assistant Superintendent of Construction A. B. See Elevator Company.

References: B. F. Stangland, O. P. Cummings, F. O. Willhofft, C. E. Lucke.

EVERETT PIERCE LARKIN

EVERETT PIERCE LARKIN, Bridgeport Brass Co., Bridgeport, Conn. Born Worcester, Mass., 1882. Worcester Grammar and High Schools; B.S. Worcester Polytechnic Institute, 1904, Mechanical Engineering Course. Spent three sum-

mers, 1901, 1902 and 1903 with U. S. Lighthouse Est. (Boston), doing general construction and repair work on automatic fog-signals, boilers, whistle, etc. Since June, 1904, with Bridgeport Brass Co., in charge of the physical testing investigation of the physical properties of the commercial wrought-brass and bronze alloys; also experimenting and investigating in foundry or casting shop and in casting brass. Also experience in chemical laboratory. Present position, in General Superintendent's Office, Bridgeport Brass Co., carrying on experiments for the General Superintendent, also preparing for work in installing cost system in the plant departments.

References: J. Fred Wilson, A. L. Smith, S. A. Reeve, C. M. Allen, Wm. H. Larkin, Jr.

FRANK J. McDEVITT

Frank J. McDevitt, 336 West Rayen Ave., Youngstown, Ohio. Born Pittsburg, Pa., 1880. M. E., Lehigh University, 1904; two and one-half years' experience in general construction, power house, car barns, etc., 1898-1899, with Consolidated Traction Co. (Pittsburg) before college course. Part of year 1900 with Havana Electric Railway Co., also part of 1904-1905. Present position, assistant to J. M. Farris, master mechanic Youngstown Iron Sheet and Tube Co., engaged in general mill repairs and construction of new steel plant.

References: L. A. Woodward, A. L. Hammarberg, J. F. Klein.

ARTHUR EUGENE MICHEL

Arthur Eugene Michel, 1121 Park Row Bldg., New York City. Born St. Louis, Mo., 1880. B. S., Rose Polytechnic Institute, 1903. Two years designing draftsman with Diamond Chain and Mfg. Co. (Indianapolis, Ind.) designing parts and repairs for automatic machinery, and experimenting and testing on improved forms of block and roller sprocket chain transmission. Six months assistant manager of Publicity of International Steam Pump Co. at Worthington Hydraulic Works (Harrison, N. J.).

References: S. D. Collett, W. H. Boehm, Geo. H. Gibson.

ARTHUR FREDERICK MILLER

Arthur Frederick Miller, 300 West Maple St., Independence, Kan. Born Buffalo, N. Y., 1881. M. E., Cornell, 1905. Apprentice, Buffalo, N. Y., firms mentioned below, machine shop work. Drawing-room, draftsman with Carl Schmil, architect, Buffalo, 1896, H. L. Camphell, architect, Buffalo, 1897. Niagara Machine & Tool works, Buffalo, 1901. Shop experience, special apprentice Lake Erie Engineering works, Buffalo, 1898. Niagara Machine & Tool works, Buffalo, 1900-1902. N. Y. C. & H. R. R. repair shops, Depew, N. Y., 1903. 1905-1906 was Asst. to Supt. Petrolia Compressor Station, Kas. Natural Gas Co. During this time was engaged in designing auxiliary buildings, supervising their construction, staking out foundations of various kinds, levelling and lining engines and generators. Present, Asst. to Chief Engineer, The Kansas Natural Gas Co. Engaged in designs for 3000 H. P. gas compressor station.

Rerefences: A. W. Smith, W. N. Barnard, R. C. Carpenter, R. G. Coburn.

JOHN J. NOLL

John J. Noll, 845 E. Mercer St., Philadelphia, Pa. Born Philadelphia, Pa., 1879. Education, Spring Garden Institute, Franklin Institute, International

Correspondence School. Drawing-room, Pedrick & Ayers Co., (Plainfield, N. J.), machine shop tools, cranes, etc., 2 years. Warren Webster & Co. (Camden, N. J.), feed water heaters, steam appliances, etc., 3 years. Present position, Assistant Chief Draftsman.

References: Warren Webster, Wm. G. Snow, A. C. Wood.

HENRY ELLSWORTH PAINE

Henry Ellsworth Paine, M.E., Chas. C. Moore & Co., San Francisco, Cal. Born Cleveland, Ohio, 1881. M.E., Cornell University, 1906. Apprentice, erecing floor Wellman-Seaver Morgan Co., June-September, 1905. Salesman with gas engine firm in Los Angeles and at present in Engineering Department, Chas. C. Moore (San Francisco). Present position, Assistant Engineer with Chas. C. Moore.

References: R. C. Carpenter, A. W. Smith, D. S. Kimball.

WILLIAM CLAUDE PARSONS

William Claude Parsons, 2433 Woodstock Ave., Braddock, Pa. Born Pittsburg, Pa., 1881. For three years under the instruction of H. H. Wood, engaged in study of the metallurgy and chemistry of iron and steel and physics. Drawing-room, Pittsburg Steel Co., June, 1901-Jan., 1902. With Riter-Conly Mfg. Co. in blast furnace department, April, 1902-December, 1905, detailing, checking and ordering material. With Carnegie Steel Company 6 mos., in laboratory of The Carrie Furnace. Present position, draftsman on gas producer work.

References: A. West, H. L. Barton, R. A. McKean.

ERIC HJALMAR AMBROSIUS PETERSON

Eric Hjalmar Ambrosius Peterson, 354 Walker Street, Milwaukee, Wis. Born Sweden, 1878. Three years high school; 4 years the Technical College in Eskilstuna, Sweden, M.E., 1897. Apprentice, erecting work Munktells Works (Eskilstuna), about four months, on steam engines, also drawing-room about one year. Two years General Swedish Electric Co. (Westeros, Sweden), electric machinery. Shop experience, machinist at the Geiser Mfg. Co. (Waynesboro, Pa.). Three years designing steam engines, portable engines, threshing machines and peat machinery at Munktells Works (Sweden) 1903-1905, draftsman for ice machines and Corliss engines, Frick Co. (Waynesboro, Pa.). Seven months Chief Draftsman at Huetteman & Cramer Co. (Detroit). Present position, Draftsman and Designer with Allis-Chalmers Co.

References: W. G. Starkweather, H. C. Ord, J. F. Max Patitz.

GEORGE ADAMS POST, Jr.

George Adams Post, Jr., Salesman Westinghouse Machine Co., 10 Bridge St., New York City. Born Susquehanna, Pa., 1883. Three years Stevens School (Hoboken); four years Cornell University, M.E., June, 1905. Apprentice, Westinghouse Machine Co. (Pittsburgh), July-January, 1906, working on turbines and gas engines. Present position, Engineering salesman Westinghouse Machine Com pany.

References: H. D. Watson, Wm. R. Roney, Louis A. Shepard.

HERBERT EMMONS RAYMOND

HERBERT EMMONS RAYMOND, 309 Lumber Exchange, Portland, Oregon. Born Massachusetts, 1881. Four years Cambridge Manual Training School; B.A., Mass. Institute Technology, 1903. Drawing work, Missisquoi Pulp Co. (Sheldon Springs, Vt.), 1902-1905, paper mill engineering. Great Northern Paper Co. (Millinocket, Me.), 1903. Portland General Electric Co. (Portland, Me.), 1906. Summer, 1899, U. S. Electric Signal Co. (Watertown, Mass.). General Electric shop work in experimental department on electric railway signals. Summer 1900-1901, year 1902, 1904-1905, with Missisquoi Pulp Co. (Sheldon Springs, Vt.). 1900-1901, machinist and draftsman; 1902, engineer in charge of construction and design of mills. 1904-1905, Superintendent and engineer in charge of operation of plant and design and construction of extensions and hydraulic development. 1903 (4 months), Great Northern Paper Co. drafting on paper mill work. 1906 Jan.-April, Portland General Electric Co., design of sub-stations. Now in partnership MacNaughton & Raymond (Portland, Oregon).

References: B. C. Ball, H. L. Coburn, Peter Schwamb, W. H. Corbett.

CHESTER TURNER REED

CHESTER TURNER REED, 60 Woodland St., Worcester, Mass. Born Kingston, Mass., 1881. M. E. Cornell, 1903. Drawing-room, Reed & Prince Mfg. Co. (Worcester, Mass.), wood screws, machine screws, rivets, etc., 1903-1904. Regular shop practice at Sibley shops, Cornell University, full course at wood working, foundry, blacksmith and machine shops. With present concern installed store room and tool department, got up automatic feeding attachment for screw threading machinery. In charge of factory stores and supplies and heat, light and power, also doing all the buying.

References: John H. Barr, George I. Alden, Milton P. Higgins.

CHARLES GARONNE RENOLD

CHARLES GARONNE RENOLD, Manchester, England. Born Alteingham, England, 1883. Education, 1 year Owens College with special work at Manchester Technical School. M. E., Cornell, 1906. No regular apprenticeship. 1905-1906, drawing-room of Hans Renold, Ltd., Manchester, England, working on inventory system and also detailing for the machine designers. Shop experience, worked with Norton Grinding Co., Worcester, Mass., vacation 1904 as general machinist. Has been employed by Hans Renold, Ltd., to investigate special cases of drives (by steel driving chains), where abnormal conditions have had to be met or unusual difficulties experienced. Superientended the design of a series of "spring wheels" for pumping, driving (by chain), to absorb the shocks and equalize the fluctuations of load. Also had in hand the arrangement of electrical equipment of new works for above firm. Present, head of raw material and testing department, Hans Renold, Ltd.

References: Fred. J. Miller, Prof. R. C. Carpenter, Dean A. W Smith, M. P. Higgins, J. M. Dodge,

GEORGE ELWOOD RHOADS

GEORGE ELWOOD RHOADS, Test Dept., Penna. R. R. Co., 1128 14th Ave., Altoona, Pa. Born Pennsylvania, 1874. Public and boarding schools; 4 years Purdue University, B.S., in M.E., 1900. Apprentice, Weatherly and S. Easton,

Pa., with Lehigh Valley Railroad, 1893-1895, on locomotive repairs. Drawing-room, Baldwin Locomotive Works (Phila.) summer vacation periods, 1899; with superintendent motive power, Penna. R. R. (Altoona), 1900-1904, engaged on design of shop structures, power and water supply plants, etc. Shop experience, machinist with Lehigh Valley Railroad (Wilkes-Barre, Pa.) for short period in 1898, on locomotive repairs. Assistant director Tests, Penna. Railroad locomotive tests (St. Louis), May-December, 1904. Editorial work on "Locomotive Tests and Exhibits" for P. R. R., Nov., 1904-1905. Present position, Engineer in Test Department, Pennsylvania Railroad (Altoona), miscellaneous testing work.

References: W. F. M. Goss, W. O. Dunbar, Chas. B. Dudley, J. T. Wallis.

WALTER BASFORD RUSSELL

Walter Basford Russell, Assistant Instructor Dept. Science and Technology, Pratt Institute, Brooklyn. Born Boston, Mass., 1874. Roxbury High School, 1897; S. B., Massachusetts Institute Technology. Sept., 1897-June, 1900, Assistant in Mechanical Engineering, Mass. Institute. September, 1900, to date, Assistant Instructor Pratt Institute, Department of Science and Technology. Three years teaching mechanical drawing. Conducted commercial tests on strength of materials, engines and boilers during six years at Pratt Institute; outlined course of teaching subject to approval of Director of the Department. One summer, 1899-1900, drafting on shoe and cotton machinery for Macleod, Calver & Randall (Boston); Assistant to R. S. Hale (Boston), one summer. Present position, Assistant Instructor in Steam and Mechanical Laboratory, teaching day and evening classes in steam, strength of materials and laboratory.

References: A. L. Williston, Henry E. Smith, E. T. Nuller.

ROY HARMAN SMITH

Roy Harman Smith, 84 Waterville St., Waterbury, Conn. Born Staunton, Va., 1879. M. E. Brown University. 1901, apprentice (Providence, R. I.), with H. Blundell & Co., jewelers and silversmiths, machinery and tools. 1896-1898, was allowed two years for shop work at Miller Manual Labor School. Drawing-room, above firm from Aug., 1896, to end of sophomore year in college. Providence Steam Eng. Co., summer 1900. Independent contract drawing and designing, winters 1899-1901. R. B. & W. Bolt and Nut Co. (Port Chester, N. Y.), 1901-1903. Waterbury Farrel Foundry and Machine Co., 1904, to present time. Further, was assistant Mech. Eng. in office with Jas. L. Bernard of the Am. Bridge Co. (Port Chester, N. Y.), Nov., 1903, to Nov., 1904. While in this position devised and put into practical operation the method of making nuts from commercial hot rolled steel. Waterbury Farrell Foundry and Machine Co., have in applications for letter patent on two machines of applicant's design. Present position, Head Draftsman, Automatic Machinery Dept. Waterbury Farrel Foundry and Machine Co.

References: Stonewall Tompkins, James L. Bernard, A. D. Finley, Wm. H. H. Kenerson, James Christie, Emile C. Boerner.

WILLIAM J. SPENCER

William J. Spencer, Wyndmoor, Pa. Born Somerville, Mass, 1877. E.E. Science and Technology Dept., Pratt Institute, 1892. Apprentice Garwood N. J., with C. & C. Electric Co.; draughting and engineering Dept., 1896. Drawing-room general draughting and material layout above company; vehicle design, shop

equipment with Vehicle Equipment Co., Elizabethport, N. J. Shop experience, lamp manufacturing testing of illuminants Bryan-Marsh Co.; general supply manufacturing as manager, W. R. Ostrander & Co., N. Y.; Inspector Electric and Mechanical Equipment, Navy Dept., N. Y. Mechanical and Elect. Engineer, qualified U. S. Civil Service Commission, for service Engineer Dept. of U. S. War Dept., in charge of design and specifications and installation of power and lighting plants, fire and control systems lines of communication, mechanical equipment sea coast fortifications. Factory Management, W. R. Ostrander. Present position Industrial Engineer, Nelson Valve Co., Wyndmoor, Pa., engaged in reorganization of plant and business.

References: F. J. Potter, Arthur H. Williston, William J. Kaup.

ARTHUR KNOWLSON SPOTTON

Arthur Knowlson Spotton, The Goldie & McCullock Co., Galt, Ontario. Born Ontario, Canada, 1874. Graduate School of Practical Science (Toronto), 1894. Drawing-room, Waterous Co. (Bradford), John Inglis Co. (Toronto), Goldie & McCullock, from draftsman to Chief Engineer. Shop experience, Barrie Electric Light Co. (Barrie) and A. R. Williams (Toronto). Chief Draftsman Jno. Inglis & Sons, 1898-1902; designing marine engines and boilers and Corliss engines. Engine designer and Chief Engineer Goldie & McCullock 1902 to present time, designing stationary engines, mainly power house work, including 1500 H. P. engines Ontario Power Co.; 1200 H. P. engines Winnipeg Elec. Ry.; 900 H. P. upright engines Dominion Steel and Iron Co. (Sydney, C. B.) and 700 H. P. horizontal engines for Dominion Coal Co. (Glace Bay), all direct-connected to 60 cycle alternators. Present position, Chief Engineer Goldie & McCullock Co., engaged in designing steam engines and boilers and power house machinery generally.

References: F. M. Rites, A. G. Mattsson, A. W. Robinson, H. H. Wait.

LEONARD GREEN VAN NOSTRAND

Leonard Green Van Nostrand, 917 Mulberry St., Scranton, Pa. Born 1881. Four years at Binghamton, N. Y., High School. Graduate Univ. Prep. School, Ithaca, N. Y., four years at Cornell Univ., Ithaca, N. Y. M. E. Cornell, 1906. At present in charge of Drafting Room, The Tonhill Iron Works (Scranton, Pa.), work done American Locomotive Works, Scranton, Pa., summer of 1905. Brake, motion and valve setting, At present, Chief Engineer of The Tonhill Iron Works (Scranton, Pa.) Personally designing two rolling mill engines, 24″ x 48″, 300 and 400 H. P. respectively, and overseeing their construction; duties also cover all estimating and general information on construction of mining machinery of all descriptions. Now holds position of Chief Engineer, The Tonhill Iron Works, Scranton, Pa.

References: Albert W. Smith, Rolla C. Carpenter, Herman Diedrich, Dexter S. Kimball.

FRED HALE VOSE

Fred Hale Vose, Instructor in Mechanical Engineering, Washington University, St. Louis, Mo. Born Milltown, N. B., Canada, 1877. Four years at University of Maine (Orono, Me.); B.M.E., June, 1900. Instructor in Mechanical Engineering at University of Maine, Sept., 1900-June, 1902. Instructor in Mechanical Engineering, Washington University (St. Louis), September, 1902, to present.

References: Robt. H. Fernald, Walter Flint, J. H. Kinealy.

THOMAS JOSEPH WALSH

THOMAS JOSEPH WALSH, 97 Howard Ave., Ansonia, Conn. Born Ansonia, Conn., 1882. Ph.B., Sheffield Scientific School, 1904. Drawing-room, Consolidated Railroad Co. (New Haven). 1904-1905, Draftsman with Eaton, Cole & Burnham Co.; 1905-1906, installed 3500 H. P. engine and foundations, sheet mill and rod mill for American Tube and Stamping Co., assistant to engineer on this work doing most of the instrument work, giving lines, levels, etc. Present position, Mechanical Draftsman on power plant, designing, engaged in redesigning power plants of Consolidated R. R. Co. for generation of electricity.

References: C. B. Richards, E. H. Lockwood, J. W. Roe.

ARTHUR SOPER WARDWELL

ARTHUR SOPER WARDWELL, 211 Lafayette Ave., Brooklyn, N. Y. Born Rome, N. Y., 1883. Four years, Rome Free Academy; M.E. Cornell, 1906; three months with York Manufacturing Co. (York, Pa.), erecting and testing refrigerating machines. June-Sept., 1905 Present position, engineers' helper with the N. Y. and N. J. Telephone Co. (Brooklyn).

References: Albert W. Smith, Dexter S. Kimball, R. C. Carpenter, W. N. Barnard, Robert L. Shipman.

JOHN CULBERTSON WHITE

JOHN CULBERTSON WHITE, 509 Wait Bldg., Decatur, Ill. Born Pana, Ill., 1868. Technical education, Chicago Athenæum Night School. Apprentice, (Mattoon, Ill.) Chuse Engine Co., machinist trade, 1886-1890. Drawing-room, 1892-1894, Chuse Engine Co. Shop experience, 1890-1892, Big Four R. R. Other practical experience, Illinois Central R. R. Shops (Chicago), E. A. Delano and Fraser & Chalmers, in each place as machinist. General Foreman for Leader Mfg. Co., July, 1897, rebuilt the Decatur, Ill., Water Works during winter of 1897-1898. General designs by C. A. Daigh—total capacity pumps 10,000,000 gallons. At completion of work in 1898 took up design of line of small gas engines for Decatur Novelty Works. Held position of Superintendent, general engineering and boiler work, M. M. Montana Ore Purchasing Co. (Butte), 1901. Present position, Consulting Steam Engineer general practice.

References: Wm. S. Love, Edward C. Wells, Thomas Hill.

LOUIS MILTON ZAPP

LOUIS MILTON ZAPP, 624 American Trust Bldg., Chicago, Ill. Born Louisville, Ky., 1880. Eleven years Louisville public and manual training schools; B.S. in E.E. Purdue University (Lafayette, Ind.), 1902. Drawing-room, general drafting and design A. G. Richay, Indiana Union Traction Co. (Anderson, Ind.), June, 1902-April, 1904, during which time designed power station for Central Illinois Traction Co. (Mattoon, Ill.), in addition to that required by the building of substation and power station for the Indianapolis Traction Co. E.E., Supply Co. (St. Louis) April, 1904-Feb., 1905. Chief Engineer power station and substations, Grand Rapids G. H. & M. R. R., February-October, 1904. Constructing E. E. (Chicago), Milwaukee Elec. R. R. Co. (Highwood, Ill.), Oct., 1905-May, 1906. Present position, Assistant to A. L. Drunn, A. L. Drunn & Co. (Chicago).

References: JAMES Lyman, W. F. M. Goss, M. J. Golden.

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THE EVOLUTION OF GAS POWER

By F. E. JUNGE, BERLIN, GERMANY
Member Verein Deutscher Ingenieure

1 The conservation of the world's natural resources, both by economic methods of production and by scientific means of transformation, tends toward the stability of modern industry and is essential to the life and prosperity of future generations.

2 Great savings in the world's supply of fuel materials cannot be made unless recourse is had to the elimination of traditional methods of production which have largely stood in the way of economical progress, and to the adoption of novel means of generation which effect the transformation of fuel energy into mechanical power in a more direct and efficient way. To the achievements already realized in this direction, there has lately been added one that even a few years ago would have been deprecated by the conservative engineer as a more or less fantastic and impossible dream, namely, the gasification of inferior grades of fuel, the utilization of waste products, and their direct conversion into useful power in gas engines.

3 Who can help admitting that the employment of gas power has actually become a factor of consequence in the world's total energy output when it is considered that in Germany, a small country of four-fifths the size of Texas, there are today in the iron and coal industry alone in active service or in contemplation, 136 gas blowing engines with 161,300 h.p., 200 gas dynamos with 206,300 h.p., 11 gas engine roll drives with 17,000 h.p., and 47 coke oven dynamos with 40,000 h.p., besides 4 engines with 1500 h.p., for other purposes, or a total of about 400 large gas engines with a combined capacity of 420,000 h.p.

4 As in the case of every other technical innovation the early period of growth of a novel method of energy making must needs be sporadic and must encounter competition in order to gain strength together with progressing expansion. Isolated inventions even if commercially sound will fail unless technical science and the development of appliances are correspondingly advanced.

5 The Diesel engine stands as an example of this fact. Conceived some twenty years ago, it was not made a commercial machine until quite recently. The difficulties in finding suitable materials that would stand the enormously high temperature and pressure stresses,

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the absence of automatic machinery and other facilities which would allow its manufacture to be put on a commerical footing, the impossibility of finding among the rank and file of engineers a sufficient number of men that could be trained to attend the new engines successfully—all these things proved obstacles in the path of the industrial adoption of this new invention. We were all convinced at the time that it marked a truly wonderful link in the chain of energy transformation, despite the fact that the theoretical predictions of the inventor were not borne out in later practice.

6 A similar experience was true of the Brayton engine, of which we find mention in Dr. Lucke's "The Heat Engine Problem."[1] Without indulging in visionary prophecies, it may be said that the working process of this engine is bound to find more general recognition in future practice if the ideal, which we are striving after in gas engine engineering is to be realized, namely, "regulable and enforced combustion of a precompressed dynamic medium of air and fuel in quantities determined by the cut-off from the engine governor according to the load," or speaking in terms of the cycle: "a process composed of adiabatic compression, heat influx at constant maximum pressure, adiabatic expansion, and heat efflux at constant atmospheric pressure." But Brayton was hopelessly ahead of his time, and glancing over the discussion which followed the reading of the paper mentioned, you will find that even Brayton's distinguished interpreter was not understood. And it is likely that even today there are but few competent observers who will admit that there is salvation beyond the present standard design.

7 This presentation, however, could not be complete if reference were not made to the probable future development of gas prime movers. For the ideal process of continuous combustion, it matters not whether the fuel burnt is gaseous or liquid, the distinction being a mere incidental and external one. With every internal combustion engine the goal is the unstraining of gas from a higher to a lower tension, preferably down to the limit of atmospheric equilibrium. All present typ s of gas, oil, gasolene, and alcohol engines are included under this designation. They also are continuous combustion engines in a certain sense, though this feature is an unsought for and undesirable phenomenon accompanying the peculiar working process. The term "explosion" is incorrect when applied in this connection.

8 In order that combustion be brought about it is necessary that air and fuel should be introduced in correct proportions under similar

[1]See Transactions, Volume 23, p. 202.

cyclic conditions during the entire range of load. Further, the two constituents must be perfectly mixed when entering the cylinder, in order that each fuel molecule may find its corresponding quantity of oxygen which is necessary to support combustion. Finally, since combustion of the charge particles causes a rise in internal pressure, while the initial piston stroke tends toward its reduction, the rapidity of heat influx must bear a certain fixed relation to the piston speed, in order that the two counteracting influences may be equalized and continuous combustion at constant pressure be secured. In the Diesel engine, of which Fig. 1 shows the theoretical working cycle, none of the above conditions are brought about. We have a constant body

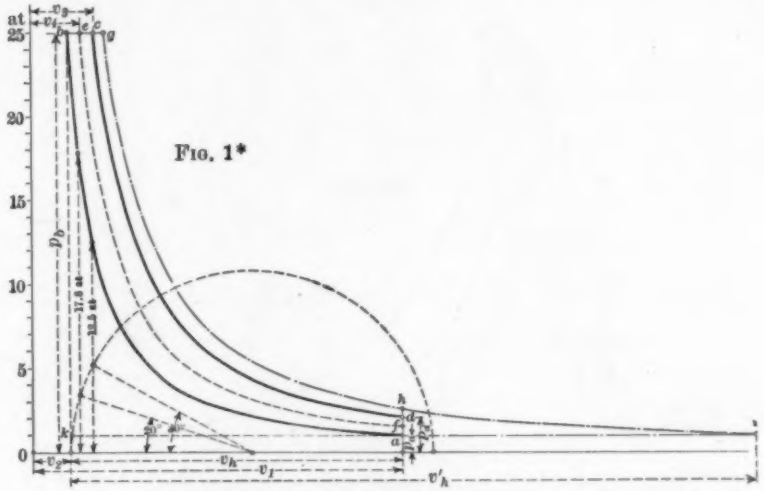


FIG. 1* THEORETICAL WORKING CYCLE OF DIESEL ENGINE

FIG. 1 THEORETICAL WORKING CYCLE OF DIESEL ENGINE

of air to support combustion, a pressure of the injected oil vapor which does not bear a fixed relation to the varying internal pressures, and, therefore, a speed of fuel influx which is irregular and one which in no way corresponds to the piston speed of that period. Nor does each fuel molecule on entering the cylinder find at once its corresponding quantity of oxygen. This feature retards ignition and flame propagation and makes the combustion a seemingly continuous one, though what we actually see is after burning.

9 It was only after long and costly experiments with various forms of inlet nozzles that an artificial retardation of heat influx was finally obtained and the desired pressure balance secured. Yet to the casual observer, the Diesel engine appears to be representative of the continuous combustion type. Notwithstanding these deficien-

cies, the thermal results of the engine are so excellent that it is truly indicative of what we may expect on a further approach to the ideal process.

10 Attention is called to an essay by Carl Weidmann, D.E., of the Technische Hochschule, Aix la Chapelle, Germany, on the enforced regulation of combustion in heat engines. In this he describes his new engine, designed with a view of utilizing the experience gained with the Diesel engine. The Weidmann engine is similar to that of the Diesel in that gasified fuel is injected into a highly compressed body of air in the working cylinder, with the remarkable difference, however, that a corresponding amount of air is introduced with the fuel by

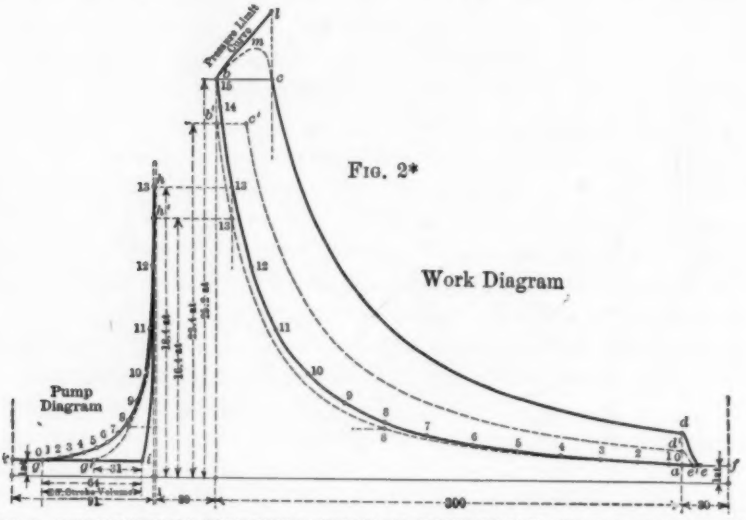


FIG. 2 THEORETICAL WORKING CYCLE OF CONTINUOUS COMBUSTION ENGINE (WEIDMANN)

a receiver piston moving at a rate corresponding to the speed of the working piston. The fuel and the air are so intimately mixed that combustion must regularly occur. Fig. 2 gives a theoretical diagram of the proposed process, from which the inventor calculates a thermal efficiency of 50 per cent.

11 The engines of the Otto type, as constructed by leading manufacturers, have been developed to a state of high perfection. Their deficiencies and incidental phenomena have been so far eliminated that the enthusiastic advocate of gas power is apt to overlook them entirely. Yet of ten indicator cards taken under identical conditions from the same engine, every one will reveal its fundamental weakness,

namely, the impossibility of controlling the combustion which is the most important function of the working process. The irregular and imperfect mixing of the charge constituents, the possibility of premature ignition and after burning are drawbacks of the present working cycle of gas engines. Of these Fig. 3 gives the diagrammatic representation.

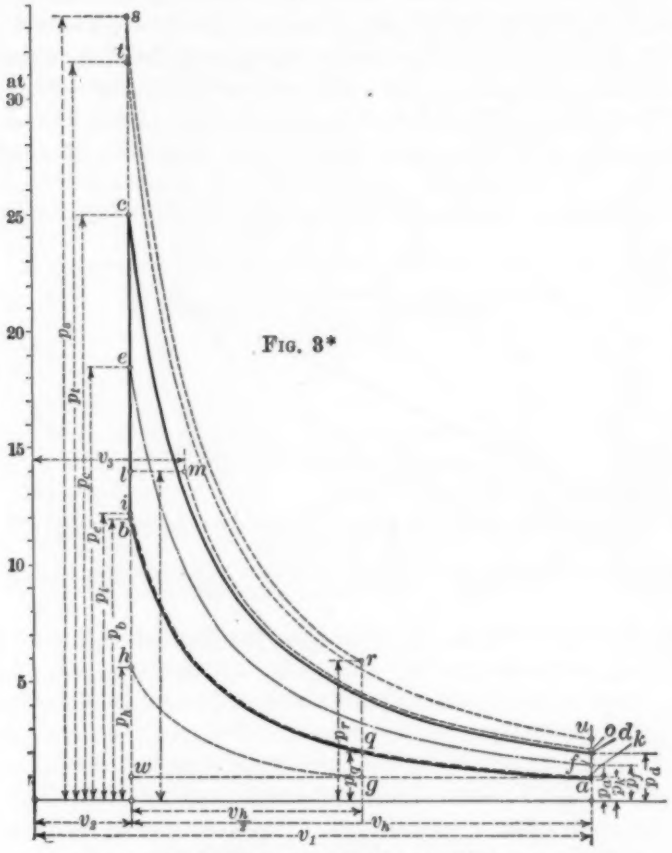


FIG. 3 THEORETICAL WORKING CYCLE OF OTTO ENGINE

12 Various attempts to improve on the working process as carried out in standard engines (as by prolonged expansion, compounding, and water injection) have proved to be entries on the wrong side of the balance sheet. The drawbacks common to all of these so-called improvements are increased bulk, weight, first cost, and negative work expanded. The best method of prolonging expansion is by high

compression of the dynamic charge before combustion. The most economical way of reducing heat losses through the exhaust is by utilizing the same for raising steam in an exhaust boiler. As high as 160 lbs. per sq. in. can in this way be generated and used for factory heating or other purposes. Generally 10% or more of the total output can be recovered from the exhaust of gas engines. Even the interesting experiments of that distinguished authority, Mr. Dugald Clerk, in which he tried to improve on the working process by increasing the density of the charge before compression, have failed to effect any considerable advantage. The additional neutral gas he used, though it reduces temperatures all around, tends to retard the influx of heat, and thereby promotes after burning and heat loss through the exhaust. The combustion process pure and simple, as used in the standard types of engines (the Nuremberg, the Koerting, the Oechel-

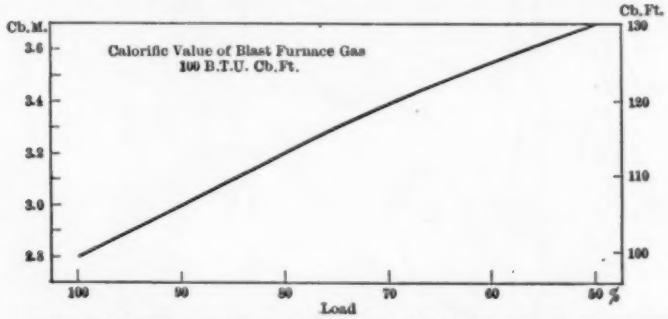


FIG. 4 GAS CONSUMPTION OF OLD TYPE BLAST FURNACE GAS ENGINE FOR ONE EFF. H. P. HOUR AT VARIOUS LOADS

hauser, the Cockerill, the Westinghouse, the Reichenbach, etc.) gives the highest economic efficiency attainable with the Otto cycle.

13 Another practical drawback, and one that cannot be overcome by the highest engineering skill because inherent in the cycle, is the lack of overload capacity in gas engines and the fact that the range of economical load is limited to only a fraction of the total. This is by no means as small as is usually held. Fig. 4 shows the rate curve of gas consumption of large blast furnace engines of an earlier design as obtained on the continent from several years of actual practice. It is seen that the line of gas consumption per B.h.p. presents characteristics similar to those of the steam engine, rising from 100 to 130 cu. ft. when the load drops from full to 50 per cent of the maximum. Another unfortunate characteristic of the gas engine is its lack of overload capacity. This often militates against its adoption and is especially felt when operating urban and interurban railway plants. It

can be compensated either by a storage battery of sufficient capacity, or by an auxiliary steam turbine system as proposed by Stott, or by the installation of spare gas engine units with a corresponding equipment for gas storage or instantaneous generation. There is no prime mover that lends itself better tot he latter application, especially as since the employment of compressed air, gas engines can be started quite as easily as steam engines.

14 Since the majority of failures of gas power plants have been due to the fact that the engines selected were too small for the maximum duty which they were expected to perform, the rating of gas engines should be standardized and the public should be advised by the manufacturers that for a service with heavy overloads, such as

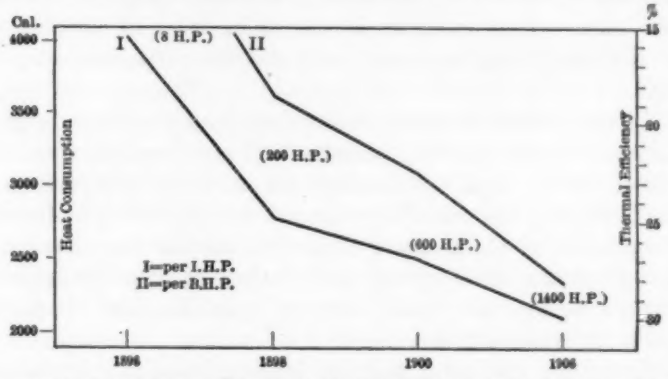


FIG. 5 TABLE SHOWING INCREASING EFFICIENCY OF GAS ENGINES (BELGIUM)

occur, for instance, when driving rolling mills, the capacity of gas engines must be considerably larger than that of steam engines.

15 Though the ideal after which we are striving is still far from what we have actually attained, it would be wrong to conclude that the present type of gas prime movers is not on a high level of excellence, not only as an economical, but as a reliable machine. Just as the steam turbine cannot be regarded as having reached its highest state of perfection and yet is a commercial engine of the greatest possibilities, so it is with the gas engine. After having passed out of the costly experimental state and after having reached a condition of standard design, its manufacture is now as profitable to the engine builder as its application is to the power consumer.

Fig. 5 shows how improvements of design and construction have gradually lowered the consumption of heat per unit output in gas engines.

16 The variety of earlier forms has now been reduced to two classes, (1) the double acting tandem four cycle engine, and (2) the double acting two cycle engine. The single acting type of each is only applicable in the smaller sizes. Each type has its disadvantages and each its special field of application. The four cycle is used for general power work and the two cycle for blowing service, and wherever variable and low speeds are essential. There is a tendency towards the employment of higher speeds in large gas engines, in order to reduce the first cost also of the generator. Therefore, since the peculiar process of charging with an open exhaust limits the two cycle engine to speeds of from 80 to 100 as a maximum, this type is at a disadvantage. It would lend itself better to the building of vertical engines. Vertical engines promise great savings in manufacture and of course in floor space. They must be developed in order to compete with steam turbines in space economy, and also for purposes of ship propulsion.

17 Of the various methods of regulation applicable in large gas engines, namely, the quality, quantity, and combination system, the last named (as developed by Reichenbach and Mees) is superior to all, because it reduces the calorific value and the quantity and therefore the compression of the mixture at the lower loads less than do the others. Therefore, more regular and efficient combustion is secured with decreasing load and lean mixtures, especially when the point of ignition is automatically advanced.[1]

18 Regarding the latest thermal performances of internal combustion engines, attention is called to, (1) a 14 h.p. Manienfelde alcohol motor and a 70 h.p. Diesel oil engine showing on test an indicated thermal efficiency of 41.7 per cent, (2) a 20 h.p. Gueldner gas engine running on city gas with 42.7 per cent, and (3) a 500 h.p. Borsig-Oechelhauser coke oven gas engine with 38.6 per cent. These figures refer to approximately full load conditions. Therefore, one h.p. indicated in the cylinder of the best gas engines so far on the market requires the expenditure of only 1490 calories or 5900 B.t.u. The economic efficiency of the latest types of gas engines, based on the actual output of available work is, therefore, between the limits of 32 and 33 per cent.

[1]For detailed information on problems of design, refer to Dr. Lucke's "Gas Engine Design," to Gueldner's "Design and Construction of Internal Combustion Engines" and to the author's treatise on "Design, Construction, and Application of Large Gas Engines in Europe," published in "Power," New York, beginning November, 1905.

19 Engineers who either have antagonistic attitudes toward the above undeniable performances or are prone to adopt them, usually try to belittle their economic importance. They point out that in proportion to the relative value of the several elements which determine the commercial economy coefficient of a heat power plant, the factor of fuel expenditure is not the most important item of expense. They say, further, that it is often completely overborne by the fixed charges, especially by the interest on the initial cost of equipment, which is for gas still higher than for steam per h.p. output, though some manufacturers have succeeded in almost equalizing this difference. Yet it must be borne in mind that even so small a saving as 1/100 of a cent per h.p. hour amounts, with a plant of 1000 h.p. output and 3000 working hours, annually to a total of $300 a year. Figuring on 10 per cent amortisation, the improved machinery which effects this saving may cost $2000 more and will yet give a net annual saving of $100. Since the reduction of gas consumption by the adoption of gas engines in place of gas fired boilers and steam engines is generally in the proportion of 3 to 1, the factor of fuel cost is by no means a negligible quantity in the h.p. hour calculation. This is especially true where power is directly needed, and, with low gas economy, recourse must be had to costly boiler coal, as is the case in iron smelting plants and collieries. The savings effected by the installation of cheaper turbo-dynamos do not offer anything near an adequate compensation for the increased expenditure in plant fuel cost.

20 In large power plants the item of fuel cost is composed, besides the price for the coal, of the expense of handling it between the car and the ash pile, including sufficient fuel storage capacity to guarantee permanence of production during all emergencies, and especially against interruptions in the supply service, such as are occasioned by strikes, railroad accidents, car or locomotive famines, etc. It is obvious that with the reduction of the fuel bill to one-third, the interest on the amount of capital locked up in the coal stored, and in the storage equipment, as well as the cost of operation and upkeep, are correspondingly reduced. With the same investment the gas power plant can tide over periods of fuel shortage, and keep up production when the steam competitors would have to shut down.

21 The question of fuel valuation which comes up when studying the comparative cost of power plants and their economics has still another aspect. The present attitude is that the cheaper the fuel the less profitable it is to use gas power in a plant. If, therefore, a gas power plant cannot effect a saving in the cost of labor, supplies, and repairs, over what is obtained with steam, there will be a definite

economic limit fixed which is determined by the price of fuel, and beyond which there is apparently no hope for gas power. Curves have been plotted showing diagrammatically the comparative cost of a gas and a steam installation. When first plotted they were equal for coal in the neighborhood of $2 per ton. A year later it was shown that the two cost lines crossed at a point corresponding to a value of coal of one dollar per ton. It has been suggested that a further reduction in the price of gas power machinery may eventually tend to effect a crossing of the two curves at the zero point of the cost of coal. This would mean that when fuel can be had for nothing, both plants can deliver power at the same cost.

22 In the iron and coal industries blast furnace and coke oven gases are available as a by-product and may be used for the generation of power. These gases were formerly wasted, either by inefficient methods of transformation or by blowing them into the air. They were, therefore, called waste gases and were marked in the columns of plant economics as having no commercial value whatsoever. It is now regarded as correct to appraise these gases at a rate, (1) corresponding to that of a certain weight of coal of thermal equivalence, (2) to the amount of steam that can be generated by a certain measure of both fuels, or (3) to that of some other standard depending on local conditions.

23 It is apparently a mistake to regard any kind of combustible matter as having no value. There are, of course, cases especially in a new country with undeveloped fuel resources and desert districts where that value is not immediate and practical.

24 There is so much being said just now about the realization of ideals in industrial pursuits that it is surprising to find in the conservation of fuels no trace or effect of such doctrine. All power plants are designed with the ultimate object of being producers of wealth for the present owners and with no regard for future activities. But even when guided by purely material motives, it is well to remember that the valuation of property is subjected to great fluctuations brought about by the rapid expansion of industries and the development of new branches.

25 An iron smelting plant having steam turbines and gas fired boilers in the power station may at present consume all of its available gas in the blast furnace and steel works. If a corresponding allotment for rolling mills is to be added, or if other industries are attracted to settle in the neighborhood, or if some community or city would build up in the immediate vicinity of the plant to whom it might be desirable to sell power at a profit, then the works management would

be confronted by the necessity of either buying good steam coal, or else of consigning steam turbines and boilers to the scrap heap and of replacing them by gas engines able to generate the required additional energy from the available gases or other waste at no additional heat cost.

26 With the rapid spreading of industries at this time, it is wise to design power plants with a view to prospective rather than to immediate earnings. Therefore, comparisons of the cost of different types of plants are not only for the most part inaccurate, but are also of local and momentary value. Earning capacities depend on the market for the output. Markets commend the employment of the most economic methods of fuel transformation, utilization and conservation, rather than the adoption of methods which appear to secure the maximum immediate profit.

27 This question of the economic relation of a gas to a steam plant has passed into an entirely new phase since it became possible to directly gasify such fuels as cannot be efficiently used for raising steam under boilers. This brings us to the other important factor in the evolution of gas power, namely, the producer, which has helped to conquer for the gas engine the enormous and practically unlimited field of application which it is just beginning to enjoy.

28 The United States Geological Survey has been conducting a series of tests at St. Louis to ascertain how the different grades of bituminous coal are suited for producer work; and also how the results compared to what was obtained when firing these coals under steam boilers. A résumé of these tests was presented at the last annual meeting of this Society by Professor Fernald. Among other things the interesting fact was developed that the fuel consumption of the steam plant increased comparatively much more rapidly with the poorer grades of coal. I do not know whether these tests have been continued and extended so as to include the examination of still inferior fuels, such as cannot without difficulty be burnt under boilers. In Germany, there are three or four types of producers in operation which have been working successfully on such material as city refuse, culm banks, etc., containing often not over 20 per cent of combustible matter, and yet doing continuous service in connection with gas engines.

29 If, therefore, gas producer power plants using the higher grades of coal, such as anthracite and coke, have been able to compete with steam plants using inferior grades of bituminous coal, the situation is now completely changed in favor of the first claimant, since we have succeeded in making gas from such fuels as hitherto escaped utilization entirely.

30 The gas producer in its present form is a comparatively modern creation. Developed from the regenerative furnaces such as were employed, among others, by Siemens in the process of steel making, they found early attention in England and France. The names of Dowson and Dr. Mond must be mentioned among those who took an active part in the vigorous development of earlier forms. The latter is especially known as having evolved a producer gas system suited to the utilization of low grade bituminous coal with the recovery of by-products in form of sulphate of ammonia, which latter has found an extensive use as fertilizer in agricultural pursuits.

31 These earlier producers were of the pressure type. In them steam and air were blown through an incandescent fuel bed, and the gas thus generated was stored in a holder. Their sphere of application was considerably reduced by the invention of the suction producer, which was first developed by Benier in France, and by Koerting in Germany. Its apparent advantage consists in that the gas making apparatus is under suction instead of under pressure, since air and steam are drawn through the fuel bed by the aspirating action of the engine piston. No extra coal fired boiler is required for raising steam. This performance is left to the sensible heat of the gases leaving the producer. The bulky gas holder is also eliminated.

32 Suction gas plants are, therefore, very simple, safe, and reliable in action, and have found an extensive field of adoption in Europe and also a limited sphere of usefulness in this country. The lower grades of American fuels present characteristics less suitable for gasification than are possessed by the European coals. It cannot be said that the gasification of coking coal is an accomplished fact. In Europe there is no lower limit in grade of fuels. At the same time another and no less important problem has been solved, namely, the cleaning of the gas from tar and other impurities which are formed during the transformation process. This is done by converting the tarry products into fixed gases in the producer proper, either by blowing or drawing the unstable volatiles through the principal or through a second zone of combustion where they are transformed into stable constituents which do not separate from the gas when being cooled. No complex and bulky cleaning apparatus is required, except an ordinary wet coke scrubber and means for drying. The question of tar extraction and disposal is thereby effectually solved and the gas is enriched accordingly. It appears even that the utilization of other available tar as additional fuel for use in gas producers gives promise of success.

33 Regarding the general design and the constructive principles of gas producers, we cannot refer to a condition of standardization

such as obtains with gas engines. This would be true even if fuel characteristics were identical all over the world, since there is as yet no accurate knowledge even of the most fundamental features, as, for instance, form and dimensions of producer chamber, kind of grate, material for firebrick lining, water cooling of producer walls, size and location of gas flues, manner of air admission, rate of gasification, depth of fire, stationary or revolving ash table, effect of automatic feed, internal or external boilers. In short, it may be said that almost everything in the design is done by traditional methods not based on adequate experimentation and data. Of course, there are three or four different systems solving all of these problems in a fairly satisfactory manner, but there is little scientific knowledge available as to which of these is the most efficient. This is one of the many cases where technical practice goes its own and independent path toward an economic aim, neither aided nor obstructed by scientific knowledge, which can only construe a theory on the basis of experiments made on the new and successful machine after the same has been completed.

34 Some of the above problems have recently been solved to a certain extent for European fuels. Thus it was found advantageous for the lower grades of bituminous coal, to make the producer proper of cast iron with water cooled walls. This eliminates clinkering entirely. The cooling effect of the water does not extend very far internally but only affects the layers located at the extreme outside. The influence on the combustion process proper is, therefore, inconsiderable. Further, it has been found that the continuously revolving ash table was wasteful in consumption; too much coal passing through unburnt, and that it disturbed the quiet action of the fire by constantly breaking up the numerous small gas passages in the fuel bed. Finally, it was found advantageous to have some preferably automatic control of the blast or of the suction pressure effecting gasification in order to be able to reduce or to increase the rate according to the condition of the fire or the load on the engine or station. In experimenting on this latter condition, it was found advantageous to insert between gas engine and producer a fan the speed of which is automatically varied according to the engine or station load. This increases greatly the elasticity of the plant, making the producer capable of carrying heavy and lasting overloads without affecting the engine. At the same time it eliminates spare producer units, gas holders, pressure regulators, pulsometers, and other cumbersome and expensive apparatus, and keeps the supply of gas steady and of more uniform quality.

35 The possibility of increasing the rate of gasification by means separate from the engine, as by induced draught, should be carefully investigated since it affords the desired means of reducing the cost of equipment at the same time increasing their flexibility. Fortunately, the gas producer possesses in a marked degree the desirable feature of overload capacity, which the gas engine is lacking.

36 The gas holder is one of the appliances that can be replaced by superior arrangements. As an apparatus for improving on the quality and uniformity of the gas by promoting diffusion and separating out the water molecules, it cannot be regarded as adequate, exposing, as it does, a large volume of gas to the varying and uncertain atmospheric influences of the season. As a storage tank for meeting fluctuations of load and peak loads of long duration, its value is problematical unless made very large, especially for the weak power gases. To keep a 500 h.p. engine running for 25 minutes the holder must have a capacity of 20,000 cu. ft. Long gas mains of ample section are a sufficient reserve for equalizing the pressure at short periods of fluctuations. In suction producer practice it is obvious that the large volume of gas between engine and producer reduces the suction effect of the former and the sharpness of the draught through the fire.

37 For operating gas engines on board ship, producers must have means for keeping up the temperature in the producer while the engine is running at slow speeds or stopping, since otherwise it will not start up again on account of lack of suitable gas. This can be readily obtained by keeping up the rate of gasification through the exhausting fan and returning the gas into the producer where it is consumed again, there being practically no loss but that of the sensible heat of the gas radiating through the piping and, of course, the power required for driving the fan.

38 No producer can be regarded as up to date that does not embody means of automatically adjusting the amount of water or steam admitted together with the air into the fire bed in fixed proportions according to the load, since without this arrangement, the fire will grow dead at the lower loads and the engine will not be able to pull up to a higher load again when necessary.

39 There are a great many questions that are yet unsettled, and await solution in producer theory and practice and it is gratifying to know that this Society has taken active steps toward thoroughly investigating the matter by a Committee.

40 While the ordinary anthracite and coke producers show a general similarity at least in type, the bituminous coal producers and such as burn lignite and peat, offer a striking variety of forms. We have such taking air in from below the grate, or from its circumference,

or from a central pipe, and others having the fire on top and taking air from above. Still others have two fires and take air from both sides. With the double zone producer as developed by Fichet and Heurty in France, and by the Deutz Motor Works and by Koerting Brothers in Germany, lignite and peat is the most desirable fuel to use, especially in form of briquettes. The raw fuels may also be burnt provided that they do not contain over 20 per cent of water, since otherwise the upper zone of combustion is apt to gradually wander down and therefore a second grate has to be inserted. However, lignite and peat containing excessive moisture are of little importance beyond the field of their production on account of the high cost of transportation.

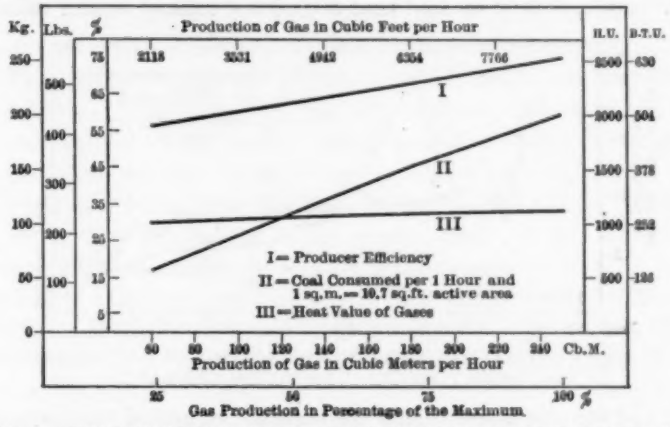


FIG. 6 PERFORMANCE OF DEUTZ DOUBLE ZONE LIGNITE PRODUCER

41 The double combustion process in itself is very simple. In the upper layers the coal is transformed to coke, the unstable gases being discharged through the incandescent zone where they are transformed to fixed gases. The coke thus formed is burnt up in the lower fire after it has been extinguished for some time in the middle zone on its way downward. The gases formed below are, of course, stable and are drawn off together with those from above.

42 While the average consumption of anthracite and coke producers is about one pound per B.h.p. hour and usually less, Fig. 6 shows the performance of a Deutz double zone producer burning lignite as fuel. It is seen that the efficiency of the process drops from 75 per cent at full load to 63 per cent at half load. This is not a very good performance for a producer, generally speaking, since with superior fuels up to 85 per cent efficiency can be attained. But it is of greater importance for the regularity of running that the composi-

tion of the gas remains practically constant at all loads as is indicated by the curve. The economic results of these plants are excellent. An 80 h.p. plant using Bohemian lignite of 9200 B.t.u. lbs. consumed on test 1.19 lbs. per h.p. hour, corresponding to a heat consumption of 1100 B.t.u., and to a price of one-eighth of a cent per h.p. hour in the particular location. (Meissen.)

43 It is, of course, impossible to state cost prices of such fuels as are adaptable to this type of producer and to consider them as correct and acceptable everywhere, since conditions of production and transportation must necessarily differ in different localities. To give an approximate idea of what obtains in the greater part of Germany, where in the neighborhood of 7000 h.p. are generated in lignite producers alone, it may be said that 50,000,000 tons of lignite were pro-

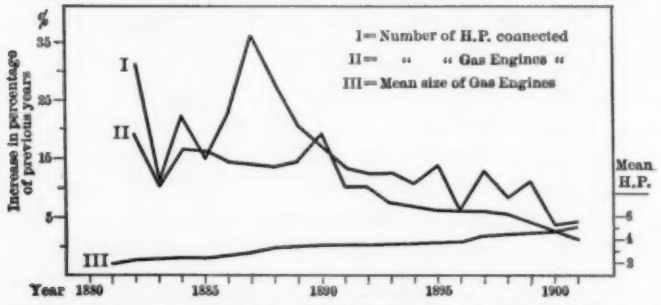


FIG. 7 TABLE SHOWING INCREASING APPLICATION OF GAS POWER FROM ILLUMINATING GAS IN 200 CITIES (GERMANY)

duced in 1905 and it seems that the stability of inland production will continue for a long time to come, diregarding entirely the importation of Bohemian coals. Since the price of average good gas coke is about three times higher than that of lignite briquettes, its heating value being only about 1½ times higher, the cost per unit power in producer gas engines is from 40 to 50 per cent lower when using lignite briquettes than when burning coke. The difference may be even greater in certain localities depending on the respective freight charges. We only need to glance at the map published by the U. S. Geological Survey,[1] showing the distribution of lignite and peat fuels in this country, in order to become aware of the impending revolution in power producing methods and of the influence and the changes which it must have in the development of certain remote districts, notably in Dakota, Wyoming and Texas.

44 The successful gasification of other low grade combustibles,

[1]Report of the operations of the Coal Testing Plant of the United States Geological Survey at the St. Louis Exposition, Part I. Field Work, Classification of Coals, Chemical Works.

such as culm banks, is performed among others in the Jahns ring producer. It consists of a series of retort chambers containing the incandescent charge at different stages of the transformation process. Through these chambers the gas is drawn in succession. After the contents of one chamber have been completely gasified, it is separated from the rest, emptied, cleaned, and charged up again to afterward enter the ring as the youngest member. In the Von der Heydt coal mine at Saarbruecken, Germany, 2100 tons of culm have been gasified, giving out a total of 40,000,000 B.t.u.; in other words, 2.2 pounds of this waste generate 7140 B.t.u. in form of available gas. The gas is used for driving gas engines and the plant has been in successful operation since 1903.[1]

45 Coming now to the third part of the subject, we shall briefly consider the application of gas power in modern industrial and other pursuits. Of all the various industries which have been benefited by the evolution of gas power, the iron industry has been the most favored, since the blast furnace as the potential source of energy not only serves to convert the raw materials into pig iron, but also produces gas as a valuable by-product. This can be used for producing the power that is required in the power plant proper, and besides leaves available a considerable surplus for other uses.

46 It is a well known fact which need not be here developed in detail that of the total quantity of gas generated in a blast furnace plant about 50 per cent is required within the plant. This includes losses at the furnace top and in pipings, viz: for driving blowing engines, heating blast stoves, operating the cleaning plant, and generating electric energy in the central station, while the rest, representing an amount equal to 25 h.p. per ton of pig iron produced every 24 hours is available for outside purposes or sale. Modern combined works often possess their own collieries and coke oven plants, which represent an additional source of available power.

47 In modern by-product ovens the quantity of gas produced depends on the quality of the coal coked, on its moisture and on the type of oven, and varies considerably in composition during one coking period. Deducting 60 per cent for heating retorts and 10 per cent for driving plant auxiliaries, there remain available for every ton of coal coked in 24 hours, from 5 to 6 h.p. for other uses. The third source of energy previously referred to, namely, the gasification of culm piles, will liberate from every ton of culm charged in the pro-

[1]For detailed information reference may be had to Samuel S. Weyer's "Producer Gas and Gas Producers." Also Mathots' "Modern Engines and Producers," and to Sexton's "Producer Gas."

ducer in 24 hours about 25 h.p., after deducting losses through deterioration, etc.[1]

48 That the total amount of useful power that can be gained by scientific transformation from the first two sources alone is no negligible quantity, will be seen when applying the above figures to American conditions. With an annual coke production of 35,000,000 tons in the United States, and utilization of the coke oven gases in regenerative ovens, there can be liberated with modern gas engines in the neighborhood of 1,500,000 h.p., if a best consumption of 8000 B.t.u. per brake horse power is assumed. With an annual pig iron production of 25,000,000 tons the surplus blast furnace gases will generate in the neighborhood of 3,000,000 h.p. in gas engines.

49 This large amount of surplus energy can, of course, be liberated only when gas power is employed for driving all machinery within the works. In small countries like Germany, England, and Belgium, the disposal of the available energy from iron smelting plants and coal mines offers no difficulty, owing to the close concentration of industrial centers. The power is partly used for electric distribution to other works or mines which have no individual power plant of their own but only possess transformer substations. Part of the energy is sent to neighboring cities for lighting and other purposes. In the majority of cases it is found advantageous to distribute the surplus energy in the form of electric current rather than as gas, though this practice cannot be generalized.

50 A third application which the surplus power has found in Germany, and which recommends itself for adoption especially in this country, is to drive electric railways for the transportation of raw materials and finished goods throughout the commercial distribution sphere of iron and steel works. It is obviously better for the iron masters to get control of the transportation factor by building and driving their own railroads independent of the railroad companies.[2]

[1] It has been found that the gain which can be effected from either the sensible heat of the gases in steam boilers, or from their sensible and their inherent heat, or from the combustion of all surplus gases in gas engines is approximately the same in the three types of coke ovens, *i. e.*, the beehive, the by-product, and the regenerative oven. In the latest regenerative ovens of the Otto type up to 140 cbm. (4940 cu. ft.) of gas per ton of coal coked are attained, the gas consisting chiefly of CH_4 and H, and having a calorific value of about 4000 calories per cubic meter (448 B.t.u. per cu. ft.).

[2] In one case where 34 per cent of the value of iron ores was formerly paid to the government for transportation charges, the independent railroad owned by the steel works has effected a reduction of this item to one-half. In other cases the saving effected was 20 cents per ton of ore delivered. These figures do not include the saving effected by the utilization of the waste gases.

51 Technically considered, this problem is very attractive, since the particular application affords a nearly constant outlet for the surplus power all year round, because the production of iron and the consumption of energy are balancing each other. When depending on unstable outside markets, we always have to introduce into the calculation a coefficient of safety. With two blast furnaces, we can only figure on the available surplus power of one furnace as forming the basis for a guarantee to an outside consumer, since a fluctuation in the iron market may require the banking of one furnace. Also the plant load factor of the proposed application becomes higher than when current is supplied to a neighboring city for lighting purposes.

52 In Germany it was planned some time ago to build a high-speed electric railway from Berlin to Vienna and to use the various iron smelting plants and collieries located along the road as substations for supplying electric energy to the line. But it was found that there was in most cases an adequate consumption of surplus power in the neighboring districts of these plants, so that there was not enough energy left available for realizing this project. In this country there are in certain localities vastly greater possibilities for operation in the direction indicated.

53 We cannot leave this part of the subject without laying particular emphasis on the fact that the gases must be cooled, cleaned, and dried before being used for the production of power in gas engines. With blast furnace gas the dust and the moisture must be eliminated not only when the gas is used in gas engines but also, though to a less degree, when it is burnt under boilers or used for heating blast stoves, etc., since plant economy is thereby greatly increased. The cleaning apparatus giving highest all around efficiency are the centrifugal high-speed type, such as the ordinary fan and the Theissen washer. The power expended in cleaning the gas can be brought down to from 2.5 to 1 per cent of the power obtained by the purified gas. The consumption of water varies from six to nine gallons per 1000 cu. ft.[1]

54 It is difficult to obtain correct figures on the total savings that can be effected in the production of iron by the application of gas power, but from 50 cents to $1 per ton of pig iron made have been recorded in various continental works.

55 In central electric stations which are located where no energy is available from near-by iron smelting plants or coal mines, the gas

[1]For detailed information reference may be had to author's articles on "Gas Power Economics," and on "The Cleaning of Blast Furnace Gas," published in "Iron Age," April, May, and September, 1906.

producer takes the place of the blast furnace and coke oven as the potential source of energy. Especially is the production of electric power at reasonable rates of importance for very large cities where the price of real estate in the centers of districts is high, and for isolated communities, country houses, and farms which are located outside the commercial radius of metropolitan or other central stations. The distribution of town gas for individual power purposes, while not so much restricted to central location within the city cannot, without loss, be extended over wide territories. Moreover, at the present price of illuminating gas, it cannot compete in the field of power production with the independent suction gas plant even if the latter use such high grade fuels as anthracite and coke.

56 Suction plants will work in the smallest sizes as economically as in the larger, and, of course, vastly more so than the largest and best equipped steam plants. They occupy very little space and may be installed in the basement of apartment and other houses without being at all dangerous or difficult to handle. Naturally the attendant must possess a degree of intelligence and training similar to one running a steam engine, though beside removing the ashes once a day his occupation only consists in filling the hopper with fresh fuel once or twice every two hours. The rest of the plant is self-regulating and needs no attention. Starting from cold does not require more than from ten to fifteen minutes. The smoke nuisance which is sometimes so objectionable in cities, is completely eliminated for all grades of coal that can be gasified. The personal equation is greatly reduced, since the process of gasification is not dependent on the skill of the fireman. Stand by losses are also very low compared to steam plants. For small work and very intermittent working oil and alcohol engines are superior, since with them fuel consumption stops entirely as soon as the engine is shut down.

57 Speaking more particularly of the generation of power from illuminating gas, Fig. 7 shows the increase of the number of h.p. delivered from city gas works, of the number of illuminating gas engines operated, and of the medium capacity of these engines in percentage of the figures obtained each previous year, all data referring to the performances recorded in Germany. During the 20 years for which data are available, the number of illuminating gas engines has increased more than sevenfold, the number of mean h.p. generated having grown in proportion from 1 to 18.

58 The price for town gas has been gradually reduced during this period, the range being represented by the two extreme limits $1.77

and 60 cents per 1000 cu. ft. in 1881 and 1901, respectively. The economy of the illuminating gas engine has in the meantime been increased in a measure represented by curves Fig. 8, which show the comparative consumption of two 6 h.p. Koerting gas engines, of which one was exhibited at the Karlsruhe Exposition in 1886, the other at the exhibition in Munich in 1898. Both tables together show how in the course of evolution the generation of power from city has grown more and more economical.

59 In order to analyze the influence of the electrical industry on the above performances, curves Fig. 9 have been plotted showing the items corresponding to Fig. 7, namely, the increase in the number

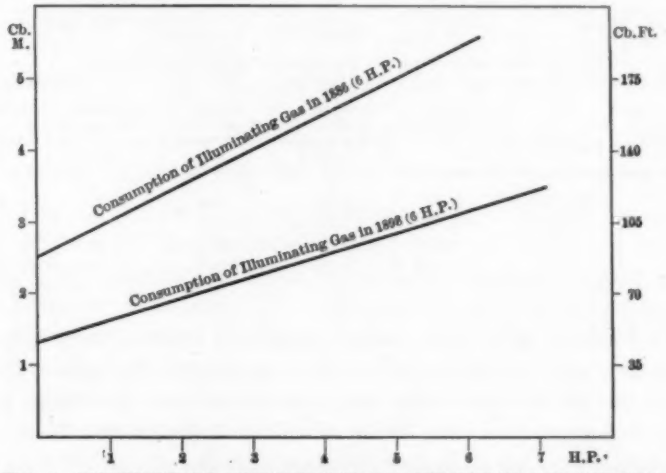


FIG. 8 CONSUMPTION OF KOERTING GAS ENGINE IN 1886 AND 1898

of electrical h.p. generated, in the number of electromotors employed, and in the mean capacity of these motors. A careful comparison of all the items bearing on the statistics of both gas and electric power application during the above period in Germany established the following conclusions.

60 A The mean capacity of gas and electromotors operated from central plants has continuously increased.

61 B The annual working time of gas engines compared to that of electromotors bears a ratio of 10 to 4, the amortisation figured on the h.p. hour of both is, therefore, approximately the same.

62 C The price of current from electric central stations for power purposes has remained practically the same from 1897 to 1901, but the price of illuminating gas for power purposes has been lowered.

63 D The increase in the number of electromotors connected with public central stations is considerable, while that of the gas engines is small, one of the main reasons being found in the introduction and growing application of the independent suction gas plant. In order that the gas companies may not lose control of the situation entirely they will have to reduce the price for illuminating power gas considerably.

64 E From the data at hand it is impossible to ascribe the fact of the small increase of the number of gas engines connected with city gas works to the influence of the growing central station business.

65 F The price per h.p. hour from gas engines had in 1901 been reduced to about two-fifths of what it was in 1886.

TABLE 10

PERFORMANCE OF SUCTION GAS PLANTS IN BERLIN (GERMANY)

BLOCK	KW. HOURS RENDERED	COAL CONSUMED LBS.	COAL CONSUMED PER KW.HOUR LBS.	TOTAL COAL CONSUMPTION LBS.	OIL CONSUMED PER KW. HOUR GRAINS	COAL CONSUMED PER B.H. P. HOUR LBS.
1	370,774	654,597	1.78	7,249	137	1.11
2	273,913	481,708	1.76	4,349	120	1.10
3	273,354	506,722	1.84	3,068	129	1.14
4	183,978	350,020	1.89	2,008	74	1.18

66 A few words may be said on the results attained with independent suction gas producers in the course of the last few years. In the central part of Berlin where real estate prices and electricity supply conditions are very similar to those which obtain in New York, there are quite a number of independent suction gas plants installed serving to deliver electric energy to individual blocks. In Table 10, the operating results obtained from January, 1904, until April, 1905, in one of these independent block stations are shown. It is seen that the average continuous fuel consumption per kw. hour is about $1\frac{3}{4}$ lbs. of anthracite, corresponding to a price of a little more than half a cent. These results do certainly encourage further efforts towards independence from public central stations. But they may even be improved upon by using lignite briquettes, with which a consumption of only 1.76 lbs. per kw. hour is guaranteed by German manufacturers.

67 Fig. 11 gives a comparison of the cost of power in over 220 towns and districts of England from the three sources, (1) public electricity supply, (2) public gas supply, and (3) own suction gas plant. It is seen that the number of places where the respective cost

lines would cross or superimpose each other is exceedingly small, which means that in ninety-nine cases out of a hundred, it is more economical to install independent suction gas power instead of using city gas engines or electric motors, the amount of saving being represented by the ordinate distance of the respective curves.

68 In metropolitan and other pumping stations suction gas power has been adopted with great success, the duty per pound of lignite briquettes being 1,270,000 foot pounds in Germany. Table 12 shows the results attained with some of such plants in England.

TABLE 12

PERFORMANCE OF SUCTION GAS DRIVEN PUMPING PLANTS (ENGLAND)

LOCATION OF PLANT	PUMP H. P.	HEAD IN FT.	COAL PER H. P. HOUR LBS.	
Welwyn Water Works.....	1.896	120	2.17	
Paris-Plage "	13.9	137.6	1.68	
East Kent "	13.64	255	1.3	coke
	12.96	330	1.28	coke

69 The application of gas power by means of the portable gasolene engine on such farms where the cheapest forms of producing motion, viz: wind or water, are either not available or unreliable, and where steam power is too expensive and electrical energy cannot he had, has filled a long felt want. On the continent this form has been superseded by the alcohol motor, which is now to become a claimant for recognition also in this country. It would take too long to enumerate here the many farm machines which can now be operated by the adoption of gas power, accomplishing such operations as have made farm work drudgery for years. The stockman, the fruit grower, the thresher, the mill owner, will readily testify to the comforts and savings which the evolution of this new power has bestowed upon them. Yet we are only at the beginning of the new era. Just now the portable suction gas plant is coming into practical use in Germany, enabling the farmer, instead of buying expensive gasolene or convert-l ing potatoes or other valuable matter by a costly process into fue alcohol, to take the straw or hay or saw mill refuse, or other vegetable matter growing on the farm, and feed it directly to the producer to be there gasified, generating the required power at no additional heat cost. In order to get the same work output with straw four times the weight of coal and 40 times its volume must be burnt.[1]

[1]In a 70 h.p. plant a h.p. hour was obtained with only 2.31 lbs. of straw and a little less of hay. Allowing in this particular case, per h.p. hour, the sum of one cent for operating expenses and interest, and a value of $4.40 per ton for straw,

70 In sugar plantations, enormous savings can be effected by burning the bagasse in gas producers instead of under boilers. In some cases, where additional steam coal has to be transported now from considerable distances, this item of expense may by the application of gas power be eliminated entirely, since it gives from three to four times the amount of energy from the available fuel.

71 It is difficult to obtain similar data to the above in this country, since the number of suction gas plants in actual operation is too small to allow us to arrive at just conclusions as to their relative cost and fitness for competition with other forms of power generation. Conditions differ from those which obtain in Europe, in that there is even a greater variety of prices for the different grades of coal in different localities.

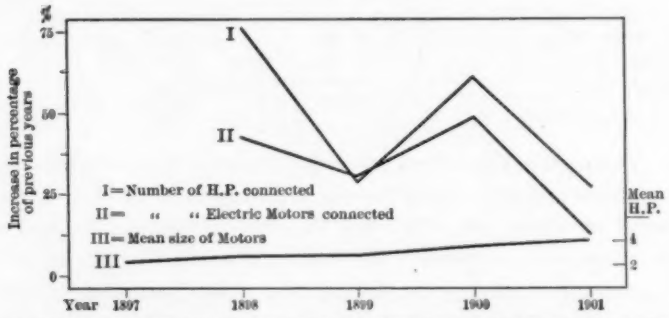


FIG. 9 TABLE SHOWING INCREASING APPLICATION OF ELECTRIC POWER FROM CENTRAL STATIONS IN 100 CITIES (GERMANY)

Further, we have in some districts, where natural gas of 1000 B.t.u. is available, a fuel which makes every other form of power production from coal practically non-competitive. But natural gas is a declining factor on which no definite claims for future activities can be based. Nor is it available everywhere, while the present enormous output of 393,000,000 net tons of coal can be maintained for an infinitely longer time.

72 A comparison of the respective cost of power from city gas on the one hand and from suction gas on the other, is even more strictly dependent on local coal prices. It is also greatly influenced by the

it was found that a h. p. hour cost 1.26 cents with wheat straw and 1.14 cents with oat straw. With the best portable steam engines coal gives the h.p. hour for 4 cents, and petrol gives about the same, while electric motors run from a distant hydraulic plant cost in the neighborhood from 12 cents to 16 cents per h.p. hour. Where the straw has no immediate value and is burned, as is the case on some American farms in the West, the application of this form of gas power generation is, of course, even more profitable.

class of service, size of engine, load factor, etc. Competition is more difficult for the gas companies, the larger the capacity and the higher the continuous load on the plants.[1]

73 It is impossible to here enter upon any sweeping statement as to what will be the probable issue of the struggle between the large gas undertakings and the consumers of power gas. Their interests are identical in that both expect to get some concession from the capital invested. This much is certain that the gas companies will have to yield to the request of continuous users for a rebate by supplying at the lowest commercial profit, otherwise the user will transfer his custom to the independent plant and the gas companies will forfeit the business. The only question still allowing of discussion is whether, even at the lowest commercial price, illuminating gas will ever rival suction gas for producing motive power, except for very intermittent loads, because suction gas besides being so much cheaper, is, if anything, better for the purpose than city gas.[2]

[1]It has been estimated that if we allow $2500 as total cost of 100 h.p. producer erected; three hours labor per day required by the producer; the engine operating ten hours a day, 300 days per year; interest, depreciation and taxes 15 per cent; engine requiring 12,000 B.t.u. on full load; then in a town where 13,000 B.t.u. anthracite coal may be bought for $6 per ton, the 600 B.t.u. gas must be sold at 27½ cents per 1000 cubic feet to meet the competition of 100 h.p. producer plant when the engine carried full load 10 hours per day and 300 days per year.

[2]Attention is called to an interesting project prepared by Mr. B. H. Thwaite, and submitted to the Parliamentary Committee on the London County Council Electric Supply Bill. The proposal was to use a current of 60,000 volts and to bring it into London over a distance of 120 miles from the coal fields. To generate the electricity it was proposed to use gas engines driven by producer gas. It was proposed to use cheap slack and the cost per ton would be only two-fifths of the cost of the fuel used by London electric generators, taking average prices. The sale of by-products would realize 2s. 6d. per ton. The land on which the generating station would be erected would be cheaper, and the saving in rates on about 100,000 kw. capacity would be about 45,000 a year, or about 9s. a year per kw., or .033d. per unit sold.

Another plan proposed by Mr. Arthur J. Martin provides for the distribution of gas under pressure as the means of conveying power from the coal fields in South Yorkshire to London. The scheme involves a transmission pipe line of over 173 miles, the gas being compressed to 500 lbs. per sq. in. At this pressure, 40,000 millions of cubic feet, which is the yearly consumption of gas in greater London, could be conveyed by a single line of pipes 25 inches in diameter. The horse power required to compress the gas would be as much as 40,000 and the cost of the pipe laying, including all incidental expenses, would be roughly, (£) 1,500,000. The annual cost of compression and transmission, including interest and depreciation, works out at 1¼d. per 1000 feet, and it is estimated from these and other figures that gas could be delivered in bulk to the existing companies at 7½d. per 1000 cubic feet, and would thus enable them to retail it at a figure which they cannot now approach.

74 As it is likely that the development of power producing and distribution in the more densely populated districts of this country will sooner or later take a course similar to that which it has taken in corresponding sections of Germany, we may expect to see an exchange of energy among the various manufacturing institutions in iron and coal producing fields. Those places where coal is cheap, or waste gases, etc., are available, but which have no market for disposing of the power, will transmit their surplus energy to industrial centers, from whence it will be distributed for further use.

75 The Rhenish-Westphalian Central Station buys power from various collieries and other cheap producers, who are glad to get rid of their surplus energy at a constant profit. A combination of this kind is especially advantageous for the small power producer, since beside running his engines all the time at the highest possible load

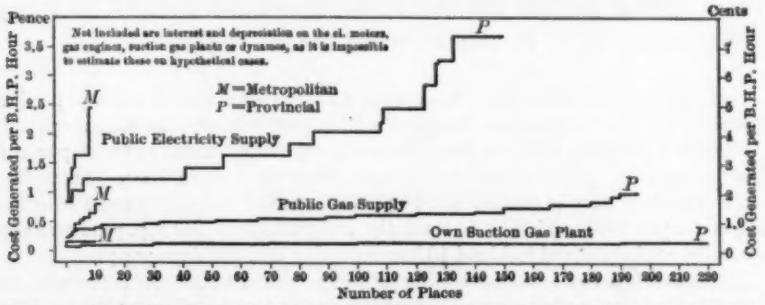

Pence
Cents
Not included are interest and depreciation on the el. motors, gas engines, suction gas plants or dynamos, as it is impossible to estimate these on hypothetical cases.
M = Metropolitan
P = Provincial
Public Electricity Supply
Public Gas Supply
Own Suction Gas Plant
Cost Generated per B.H.P. Hour
Number of Places

FIG. 11 DESIGN SHOWING COST OF POWER IN 222 TOWNS AND DISTRICTS (ENGLAND)

factor, he need not install spare units. In case of a break down he is entitled by agreement to take, for his individual purposes, energy from the line. Perhaps, if this policy of reciprocal exchange could be extended further, it might help solve the question of competition between the large central stations and gas companies on the one hand and the small independent power producer on the other. If the growing business of the large power companies instead of being met by an enlargement of their existing plants (which is often very difficult and expensive especially in large cities where real estate is high) could be amplified by the delivery of additional energy from smaller independent producers, then both parties could sell power at a profit. The small producer, whose plant may be located near the central station and who can generate gas power with as high thermal efficiency as the largest plant, would find a constant market for his surplus power, while the central station with its established business can sell this power at a higher rate, without having to install additional units

and reserves, which soon depreciate without bringing adequate returns. Of course, the larger the number of independent contributors and the smaller the amount of their specific contributions, the more difficult will be the satisfactory organization of a combination of this kind the difficulties being less of a technical than of an administrative nature.

76 Reference has already been made to the application of gas power for the propulsion of vessels. Ships equipped with suction producers and engines have actually effected a reduction of coal consumption to one-third of that of steam s' ips. This fact together with the reduction in space occupied by engines and coal bunkers, and the corresponding gain in cargo space, and the elimination of smoke and smell, make the adoption of gas power of the greatest importance for vessels which are to possess the maximum radius of action combined with the minimum cost of operation. Therefore, builders and owners of canal barges, tug boats, yachts, etc., ought to devote their most careful attention to this new development

77 While there is little or no gain to be expected in bulk and weight of the engine power, the gas producer only occupies about one-third of the space of a water tube boiler, or one-eighth of that of a Scotch marine boiler, the dimensions depending on the grade of coal burned. In a 7000 ton cargo steamer fitted with gas power, the saving in cargo space effected was 13,000 cu.ft. The weight of a gas producer compared to that of a water filled boiler of the type such as is installed in yachts and tug boats, is from one-fourth to one-fifth that of the latter. The amount of water needed for evaporation is about one-half pound per h. p. for a coal consumption of three-fourths pound.

78 On a trial run a 70 h.p. gas tug consumed in ten hours 530 pounds of German anthracite against 1820 pounds of steam coal used by the competing 75 h.p. steam tug. This economy so far affected is in the ratio 1 to 3.44 and is certainly encouraging enough to induce capitalists and engineers in this country to investigate this matter before foreign practise is getting too far ahead. For the propulsion of larger vessels, the double acting vertical two-cycle engine is the most promising type to be adopted, since it gives steady and quiet motion with variable speed, quick starting under load, and almost instant reverse when compressed air is employed, such features being the indispensable requisites for successful operation on board ship.

79 The Deutz Motor Works of Cologne, Germany, who were the first to investigate the technical and commercial possibilities of gas ships, have fitted their suction gas system on eleven vessels, the power

of the various engines ranging from 35 to 90 h.p. Recently they built two flat bottom barges of 240 tons for river traffic, equipped with engines of 100 h.p. of which one is doing active service between Cologne, Antwerp, and Rotterdam.[1]

80 During the year 5200 tons of load were carried representing 1,950,000 ton miles, which was done at a cost of about 25 cents per ton. Had the material been transported from Cologne to Rotterdam by the ordinary steamboats the tariff for transport would have been about 50 per cent higher, while the lowest rate by the railroad would have been five times as much. Another barge of the same capacity is used for the haulage of goods on the Saarbruecken-Muehlhausen Canal, making a round trip of 170 miles which occupies 30 days, including 9 days detention and 9 days with light load. Under these disadvantageous conditions the cost of transportation by the suction gas propelled craft is 33 per cent lower than that of horse traction, while the boat during the year makes eleven round trips as compared with seven complete journeys, which were possible by animal traction before the introduction of the new system.

81 In England, the firm of Thornycroft & Co. have recently built a gas barge which is equipped with a gas plant designed by Herr Capitain, a German engineer who has been very successful along these lines. The barge in question has just completed a trial run over 600 miles in open water. Assuming that the coal used is costing $6 per ton, and that the barge is carrying a net load of 20 tons and traveling at a rate of 6 miles an hour, the cost per hour for fuel is less than 10 cents, if a consumption of 1.2 lbs. per B.h.p. is allowed.

[1] The total distance traveled is 187½ miles and the time occupied on the round trip, including all stops, with an average load of 200 tons, occupies 14 days, giving an average daily run of 27½ miles under all conditions, thereby enabling 26 round journeys per year to be accomplished. The cost of the vessel was approximately $11,250 and the annual expense of operation, maintenance, etc., work out as follows:

Depreciation on hull, 5 per cent on $5000	$250.00
Depreciation on engines, 10 per cent on $6250	625.00
Interest on capital, 5 per cent on $11,250	561.50
Insurance	11.25
Navigation dues, 26 round trips	975.00
Fuel anthracite at $5 ton; burned at the rate of 1.32 lbs. per h.p. hour for 75 hours per round trip, 50 hours up-stream and 25 hours down-stream, 117 tons	585.00
Lubricating oil, etc.	243.75
Wages	1,750.00
Total annual outlay	$5,002.50

82 In a recent address, delivered by Professor Riedler-Charlottenburg to the *Verein Deutscher Ingenieure* on the evolution of the steam turbine, the situation was characterized by the following remarkable words: "A development of unprecedented rapidity of one of the most difficult motors in the history of mechanical engineering: a sweeping victory in the power station field: a momentous advance of the highest importance, principally to electrical engineering." If we consider that what was thus described is a new machine which transforms the energy of steam into useful power at a higher degree of mechanical excellence, with a saving in weight and bulk and cost of the prime mover and generator, and with a greater uniformity of turning effort, but with the same low economic efficiency, we are at a loss to give expression to the extreme importance which the evolution of gas power possesses as a factor in the field of industrial economics. It may suffice to draw attention to the fact that this is not the substitution, by a rotary type or prime mover, of a reciprocating engine of the same thermal characteristics, but the complete abandonment of a traditional and wasteful process of energy generation in favor of a direct and efficient method. It has not only extended the capacity of our fuel resources to double and more of their former value, but has also enabled us to profitably utilize material and property which was deemed utterly worthless even a few years ago.

83 We need not point out to those upon whom the technical responsibilities of this particular industry rest how far, by their earnest endeavor, they can help towards the realization of such ideals as are before us. Nor need we dwell on the effect or importance of the scientific study, in our great scholastic centers, of fuel characteristics and conversion as a means for producing proper utilization. It must be patent to all that the more broadcast the dissemination of scientific knowledge of everything that is apt to clarify and amplify our understanding of these commodities, the greater must be the industrial progress.

APPENDIX

84 Referring to Fig. 3 *abc1a* represents the ideal diagram of the Otto cycle, at full load. An initial pressure $p_a = 1$ atmosphere, a compression pressure $p_b = 12$ atmospheres, a combustion pressure $p_c = 25$ atmospheres, and a temperature $t_a = 300°$ C. were assumed. Exponent $n = 1.41$, stroke volume $v_2 = 200$ mm. scale 1 cm. $= 1$ atmosphere.

85 On this basis the following data were obtained:

Volume of compression space..... $v_a = 41.44$ mm. (1.63″)
End temperature of compression.. $T_b = 618°$ (1144.4° F.)
End temperature of combustion .. $T_c = 1287°$ (2348.6° F.)
End pressure of expansion ..... $P_d = 2.08$ at. (30.6 lbs sq. in.)
End temperature of expansion.... $T_d = 625°$ (1157° F.)

Hence the thermal efficiency at full load

$$\eta_t = \frac{Q_1 - Q_2}{Q_1} = \frac{T_c - T_d}{T_c} = \frac{T_b T_a}{T_c} = 51.4 \text{ per cent}$$

86 Assuming quality regulation and the influx of heat at half load reduced to $\frac{Q_1}{2}$ the following values are obtained: (diagram *abefa*)

End temperature of combustion .. $T_e = 953°$ (1747.4° F.)
End pressure of combustion ..... $P_e = 18.5$ at (272 lbs. per sq. in.)
End pressure of expansion ..... $P_f = 1.54$ at. (22.64 lbs. per sq. in.)
End temperature of expansion ... $T_f = 462.5°$ (864.5° F.)
Thermal efficiency ..... $\eta_t = 51.4$ per cent

87 With quantity regulation the influx of heat at half load is again $\frac{Q_1}{2}$ the active stroke volume $\frac{v_h}{2}$, and $T_g = T_a$, and the following values are obtained: (Diagram *ghikag*)

End pressure of compression ..... $P_h = 5.65$ at. (831 lbs. per sq. in.)
End temperature of compression.. $T_h = 496°$ (924.8° F.)
End temperature of combustion .. $T_i = 1068°$ (1954.4° F.)
End pressure of combustion ..... $P_i = 12.16$ at. (178.8 lbs. per sq. in.)
End pressure of expansion ..... $P_k = 1.012$ at. (14.88 lbs. per sq. in.)
End temperature of expansion ... $T_k = 518°$ (964.4° F.)
Exhaust temperature ..... $T_a = 512°$ (953.6° F.)
Thermal efficiency ..... $\eta_t = 46.8$ per cent

88 Referring to Fig. 1, *abcda* represents the ideal diagram of a constant pressure engine at full load. The initial temperature and pressure conditions are assumed to be the same as before. With a stroke volume $v_h = 200$ mm. the following data are obtained:

Volume of compression space ..... $v_a = 22.72$ mm. (.895″)
End temperature of compression.. $T_b = 765°$ (1409° F.)
Volume at end of combustion..... $v_3 = 38.22$ mm. (1.505″)
End pressure of expansion ..... $P_d = 2.08$ at. (30.57 lbs. per sq. in.)
End temperature of expansion ... $T_d = 625°$ (1157° F).
Thermal efficiency at full load ... $\eta_t = 55.6$ per cent

89 At half load the influx of heat is $\frac{Q_1}{2}$, and the following data are obtained: (diagram *abefa*)

End temperature of combustion .. $T_e = 1026°$ (187.8° F.)
Volume at end of combustion..... $v_4 = 30.46$ mm. (1.19″)
End pressure of expansion ..... $P_f = 1.51$ at (22.19 lbs. per sq. in.)

End temperature of expansion ... T_f = 454° (849.2° F.)
Thermal efficiency at half load ... η_t = 58 per cent

At no load the total efficiency of the process approaches the thermal efficiency of the elementary process which is expressed by the equation $\eta_t = \frac{T_b - T_a}{T_b}$ $\eta^t = 68.8$ per cent

90 Referring back to Fig. 3, diagram *ablmoa* represents the condition of sluggish combustion. Assuming a combustion pressure of p_l = 14 atmospheres, with continuous combustion at that pressure and the adiabatic compression curve *ab* and the end temperature of compression to be identical, the following data are obtained:

Temperature at point *l* ..... T_l = 721° (1329.8° F.)
Temperature at point *m*..... T_m = 1124° (2055.2°)
Volume at point *m* ..... v_3 = 64.6 mm. (2.54")
End temperature of expansion ... T_o = 655° (1211° F.)
Thermal efficiency ..... η_t = 47 per cent

91 Under these conditions, which correspond to those of actual practice, the efficiency drops 8.5 per cent below the ideal, while the efficiency of the constant pressure diagram is 18 per cent higher.

92 In Fig. 3 curve *aqrs* represents the condition of premature ignition. Assuming that ignition sets in at a pressure p_q = 2.13 atmospheres the following data are obtained:

Temperature at point *q*..... T_q = 373.5° (704.3° F.)
Temperature at point *r*..... T_r = 1043° (1909.4° F.)
Pressure at point *r* ..... P_r = 5.93 at. (87.17 lbs. per sq. in.)
Max. pressure at point *s*..... P_s = 33.5 at. (492.5 lbs. per sq. in.)

The possibility of such excessive pressures occurring in the working cylinder is a drawback of the Otto cycle which is not inherent in the constant pressure process.

93 An investigation of the relations between the mean effective pressures and the maximum pressures, and between the mean effective pressures of the respective cycles, which is necessary for determining the bore and stroke of the cylinder and the dimensions of the working parts, brings out the following points: With equal maximum pressures and temperatures the mean effective pressure of the constant pressure cycle is 13 per cent higher than that of the Otto cycle. With the latter, an increase of the mean pressure can only be effected by increasing the maximum pressure of combustion; with the former, by prolonging the period of heat influx. Diagram *abtua* represents such an increase with the Otto cycle, corresponding to a mean pressure of 5 atmospheres. The maximum pressure is found to be p_t = 31.5 atmospheres (463.05 lbs. per sq. in.)

The maximum temperature is ..... $T_t = 1620°$ (2948° F.)
The thermal efficiency ..... $\eta_t = 51.3$ per cent

94 Diagram *abgha* represents an increased constant pressure diagram, corresponding to a mean pressure of 5 atmospheres (735 lbs. per sq. in.)

The maximum pressure..... $P_c = 25$ at. (368 lbs. per sq. in.)
The maximum temperature ..... $T_g = 1500°$ (2732° F.)
The thermal efficiency ..... $\eta_t = 54$ per cent

A comparison between the two established the following result:

95 For the commerical range equal mean effective pressures are attained in the constant pressure cycle at lower maximum temperatures and pressures and with a higher degree of thermal efficiency than in the Otto cycle.

96 Regarding the relation of the negative work consumed to the positive work rendered, diagram *awba* represents the former and area *awtua* the latter item in the Otto cycle. It is found that the negative work is 29.2 per cent of the positive work.

97 In the constant pressure cycle area *akba* represents the negative and area *akbgha* the positive work, the ratio being 38.4 per cent. It is seen that the negative work expended is smaller in the Otto than it is in the constant pressure cycle.

98 Regarding the influence of prolonged expansion on the economic efficiency of the process, it is found to be unfavorable. By prolonging *gh* down to the atmosphere a diagrammatic area *abghia* is obtained representing a mean pressure of 2.76 atmospheres against 5 atmospheres of the smaller diagram *abgha*. This means that by prolonging expansion the mean effective pressure is reduced to nearly one-half of its value. Hence, to obtain the same capacity with equal stroke, the piston area and, therefore, the maximum piston pressure must be nearly doubled. The increasing thermal efficiency (from 54 per cent to 60.8 per cent) is, therefore, more than counterbalanced by the decreasing mechanical efficiency and by the losses through cooling.

99 Referring to Fig. 2, diagram *abcdea* represents the full load and *ab′c′d′e′a* the half load ideal diagram of a Weidmann continuous combustion engine, while *ghi* and *g′h′i* are the corresponding pump diagrams. The relation of negative pumps work expended to positive work rendered is 6.5 per cent at full load and 8.5 per cent at half load. The thermal efficiency of the process is 49 per cent and 50.2 per cent, respectively.

FIG. 1 EXTERIOR, GOULD POWER PROPERTIES, DEPEW, N. Y.
COOLING POND IN FOREGROUND, PRODUCER HOUSE IN BACKGROUND

PRODUCER GAS POWER PLANT

An Inquiry into the Operation, Efficiency, and Construction of a Typical Modern Industrial Plant

By J. R. BIBBINS, PITTSBURG, PA.
Junior Member of the Society

1 With all the present activity in power development for various purposes, industrial or otherwise, the value of the simple producer plant used exclusively for power generation seems to have been somewhat overlooked or at least questioned. Gas producers, especially for bituminous fuels, are quite familiar in metallurgical work, notably in the various iron and steel industries; and although the problem of gas purification presented in power work is somewhat more serious, yet experience has indicated several fairly simple methods of solution. The ability of the modern gas engine to take the place of the steam engine in general power work has likewise been questioned, as well as the capacity of gas engine and producer to work together harmoniously under widely varying load demands.

2 Fortunately neither of these charges is founded on a basis of actual conclusive experience, and it is the purpose of this paper to present some practical data upon the operation of a thoroughly representative commercial gas power plant; one in which a high measure of success has been obtained through intelligent engineering and supervision. Even though some minor improvements might still be suggested, the fact remains that this gas power plant is operating week in and week out, 24 hours per day, 6½ days per week, on a fluctuating manufacturing load, with a fuel consumption fully one-half that of a modern steam plant of like character and suited to the same work. On an average of half load this 450 kw. plant ordinarily consumes from 2 to 2¼ pounds of coal per K. W. H. and, on heavier loads, has reached as low a consumption as 1½ pounds per K. W. H. in regular daily running. During heavy loads the plant has repeatedly developed without the battery 530 kw. on maximum fluctuations which represents an overload of 18% rating. Furthermore, with the exception of the engineers in charge during the two watches, the plant is operated by attendants originally quite unskilled in gas work; up to the present writing, however, no complete interruption of service, traceable to defective equipment, has been recorded.

To be presented at the New York meeting (December, 1906) of The American Society of Mechanical Engineers, and to form part of Volume 28 of the Transactions.

3 These facts are thought to be sufficiently impressive to warrant their presentation to the Society, particularly as this plant may be regarded as exemplifying modern engineering practice and the service resulting therefrom. It is hoped that the considerable descriptive detail appended will be excusable as more or less essential to a full appreciation of the subject. The choice of a single example seemed to provide a better opportunity for detailed treatment.

CHARACTER OF SERVICE

4 The plant in question serves the entire Gould Manufacturing properties at Depew, a suburb of Buffalo, N. Y. Two complete works are located here; one devoted to the manufacture of storage batteries and the other to the manufacture of railroad specialties, principally automatic couplers. The latter contains a large and well equipped steel foundry. Both are electrically driven and lighted throughout from the central gas power plant.

5 Contributing to the station load are a large number of labor saving machines of different types, such as electric traveling cranes, charging tables, transfer locomotives, elevators, conveyors, fans, pumps and machine shop tools. The storage battery works also use considerable current at times for "forming" battery plates.

TABLE 1

EQUIPMENT DATA

450 K. W. PRODUCER GAS ENGINE POWER PLANT

Service—Power, some lighting.
Capacity of Plant—450 kw.
Number of Units—Three, 150 kw.
Distribution system—D. C. two wire.
Pressure—250 volts, normal 230.
Power Building—45′x 61′ inside.
Height of roof trusses—28½′.
Height of basement—9′.
Total area per kw.—6.1 sq. ft.
Net area of unit—15′x 33½′.
(With 6 ft. passageways.)
Net area unit per kw.—2.87 sq. ft.
Walls—Red brick, exterior pilasters, limestone trimmings, steel frame work.
Roof—Wood, tar and gravel, steel trusses, monitor.
Floors—Steel, wood, ¾″ maple finish.
Basement floor—Concrete.
Foundation—Concrete.
Crane—Hand power, tons.
Producer Building—Steel framework.
Corrugated iron walls and roof.
Charging floor—Boiler plate.
Cooling Pond—1,000,000 gals.
Dimensions—280′diam. x 93′ wide.
Area (Power Plant) 7,300 sq. ft.
Area (Producer Plant) 7,500 "
Total, 14,800 "
Depth—Normal 10′.
Holder—36″ diameter, single lift, 15,000 cu. ft.
Coal used—Bituminous run of mine.
Sources—Buffalo, Rochester & Pittsburg R. R.
Price—$2.30 per ton.
Heat value—13,500 B. t. u.

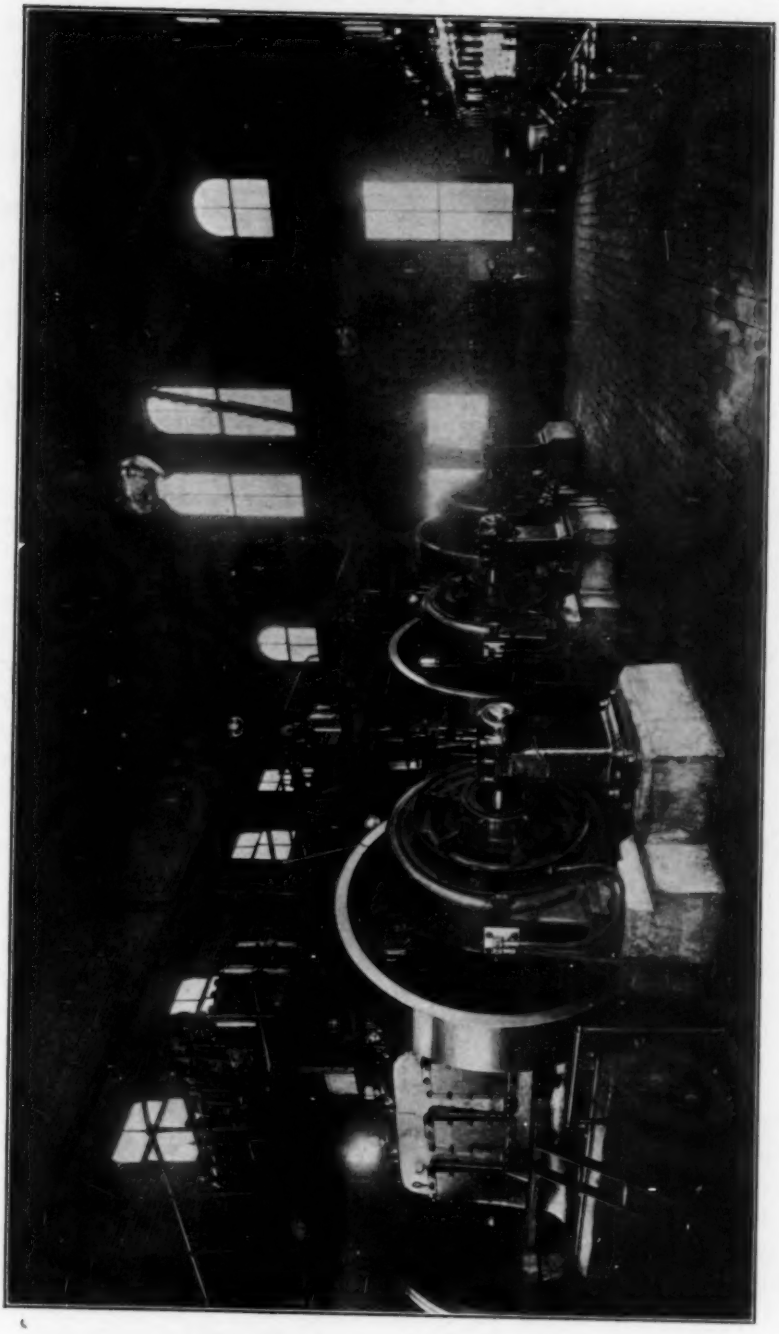


FIG. 2 INTERIOR OF POWER STATION
IGNITER CABINET AT REAR WALL, STORAGE BATTERIES IN BASEMENT

Engines—Westinghouse three cylinder, vertical gas engines.
Type—Single acting four cycle.
Capacity—235 B. H. P., 260 maximum.
Normal speed—200 r.p.m.
Size cylinders—(3) 19″x 22″ stroke.
Ignition—110 volts and 8 volts.
2 sets four cells storage battery.
1 motor generator set, ½ kw.
Cooling Water (jackets)—Motor driven centrifugal pumps. Two 2″ Worthington "Volute." 15 H.P. motor 1450 r.p.m.
Cooling Water (Scrubber)—2-stage motor-driven. 2″ Worthington "turbine" type. 15 H.P. motor.
Compressed Air—100 lbs. from works, also 6″x 6″ Rand duplex single stage compressor. 10 H. P. motor.
Generators—Westinghouse compound wound. Direct current.
Capacity—150 kw., 250 volts.
Switchboard—250 volt D. C.
Producers—Loomis-Pettibone.
Type—Bituminous, duplex intermittent blast. 3′–8′ diameter.
Boiler—5′ dia. vertical tubular, utilizing waste heat.
Wet Scrubber—6′ dia., vertical, coke, water sprays.
Dry Scrubbers—Two 9½′ dia., in parallel; excelsior, 2 layers.
Valves—gear lift, water cooled.
Exhauster Roots—Simple engine drive.
Gas Main—12″ diameter.
Gas Risers to Engine—8″.
Fittings—Screwed.
Valves—Chapman gate.
Coal Handling—Bucket elevator, motor driven.

6 Although the power station load is smoothed out to some extent by the overlapping of demands from these various sources, yet the larger machines pull heavily upon the system with the result that the load at the station bus bar is subject to violent fluctuations, easily 80% above or below (on light loads 100%) the general averages. As no system of notification is in force, the power station cannot be apprised of anticipated demands from the several production departments of the works. The storage battery forming load is, of course, steady while it exists, but it is liable to be abruptly thrown on or off at any time.

7 Several typical runs are shown in the accompanying logs, Figs. 3a, 3b, 3c, 3d, for April 13, July 11–13 and September 25, 1905, respectively. Although the recorded output is fairly steady through the day, the fluctuations correspond in some cases to overloads of 15–20% on the engines.

8 The original plant was entirely capable of handling these fluctuations, but on account of doubling the steel plant load and adding electrically driven air compressors, an auxiliary storage battery[1] was recently installed for the dual purpose of securing a more constant load on the engines with higher economy of fuel, and of increasing the average load. Formerly it was necessary to keep the spare unit constantly in service to tide over the peaks.

[1] This battery, however, was not placed immediately in service and does not affect the results presented in this paper except in the matter of capital costs.

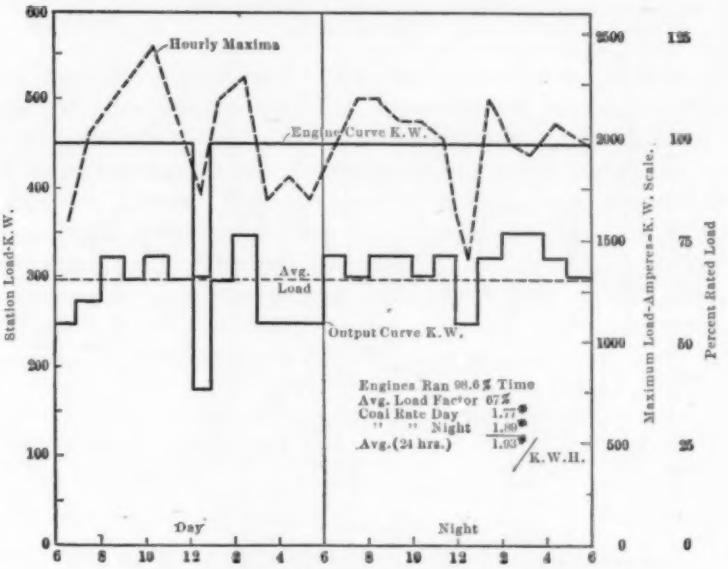


FIG. 3a LOAD DIAGRAM GAS ENGINE PLANT
APRIL 13, 1905

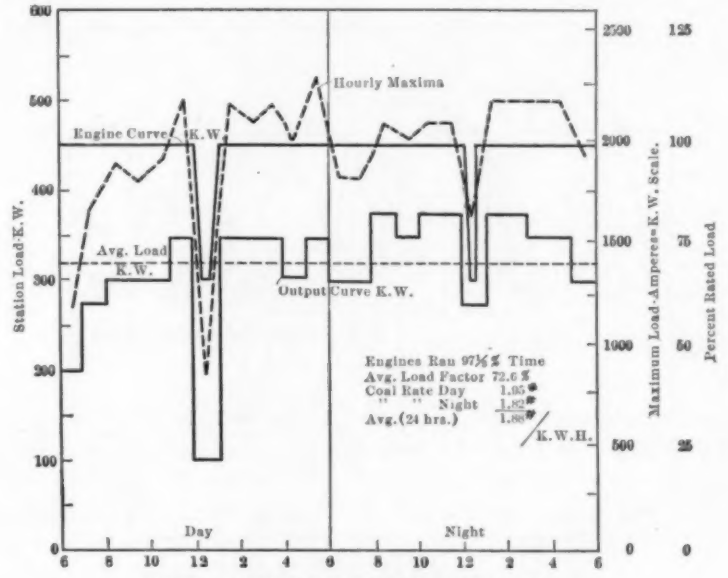


FIG. 3b LOAD DIAGRAM GAS ENGINE PLANT
JULY 11, 1905

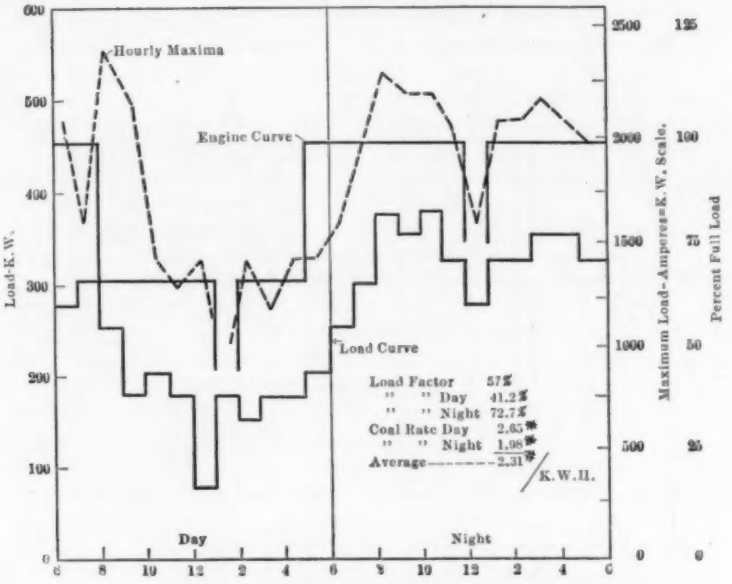


FIG. 3c LOAD DIAGRAM 450 K.W. GAS POWER PLANT
JULY 13, 1905

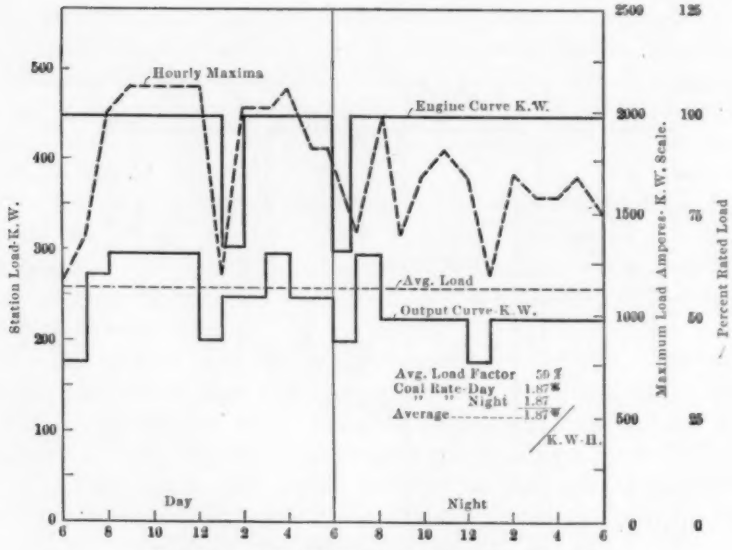


FIG. 3d LOAD DIAGRAM GAS ENGINE PLANT
SEPTEMBER 25, 1905

PLANT DUTY

9 From the daily records of the plant an excellent idea of its operative efficiency may be obtained. These records, although not elaborate, are carefully kept and show not only the output and duty of the plant but also the maximum loads that occur during the hour. A digest of a typical day's run is given in Table 2 and shows continuous operation except at noon and midnight; to be exact, 97% of the elapsed time. The load averaged 263 kw., or 58% of the generating capacity in service with nine full load hourly maxima and five equivalent to 8% overload. The average coal consumption for all purposes was 1.98 pounds per K. W. H. generated.

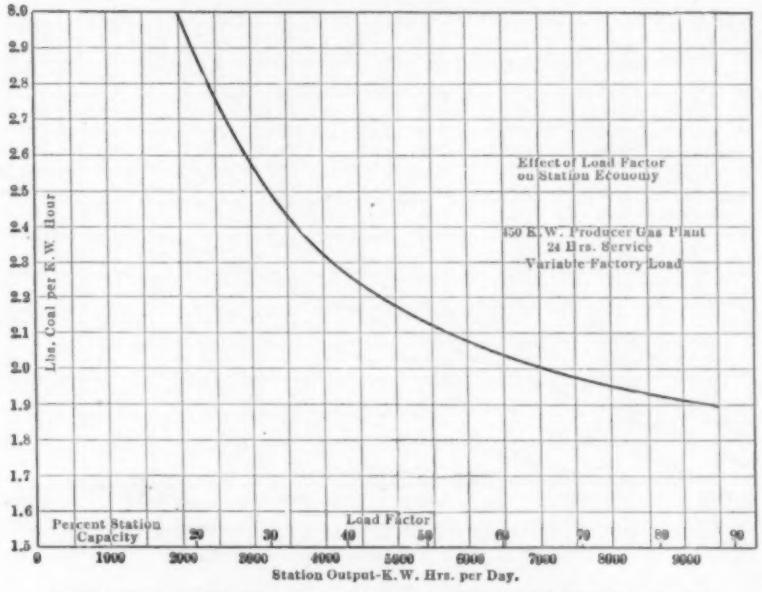


FIG. 4 RELATION OF FUEL RATE TO STATION LOADING FACTOR
(PLOTTED FROM OBSERVED DATA)

10 During a ten day run in September, 1905, the results shown in Table 3 were recorded. The engines averaged 87¼% of the possible running time and on 51% station loading factor[1] the plant consumed 2.04 pounds fuel per K. W. H., or 1.44 pounds per B. H. P.

[1]Loading Factor = $\frac{\text{Avg. 24 Hr. Station Load}}{\text{Rated Capacity}}$

True Load Factor = $\frac{\text{Avg. 24 Hr. Load}}{\text{Maximum}}$

hour. With coal of 13,500 B. t. u. calorific value the efficiency of this plant averages about 13.1%, thus rivaling, if not excelling, the largest modern steam power stations. On September 27. the fuel rate was 1.88 pounds per K. W. H. (or about 1¼ pounds per B. H. P. hour) with 62% loading factor, corresponding to a plant efficiency of over 15%.

11 The author has been deeply interested in the effect of the loading factor of a plant upon its efficiency and commercial duty. An unusually good opportunity arose in analyzing the results of this plant and the approximate relation is presented in Fig. 4. In order

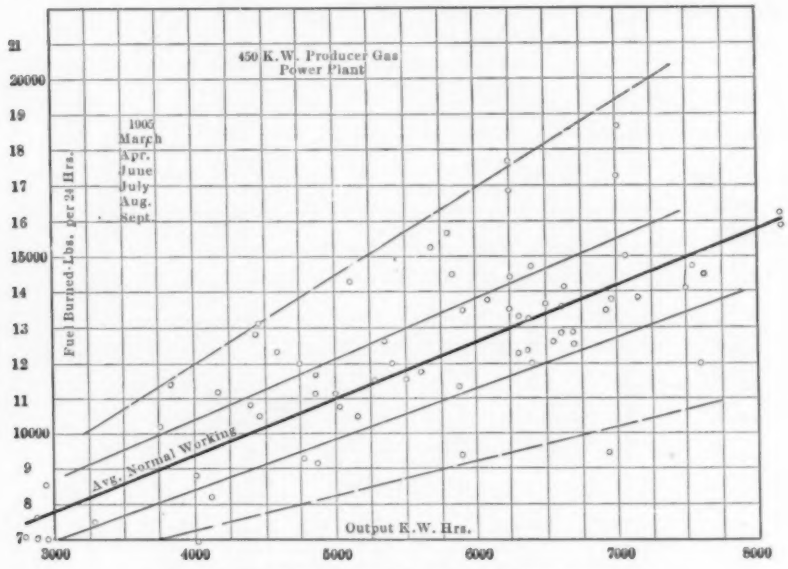


FIG. 5 FULL CONSUMPTION AT VARIOUS OUTPUTS
(GRAPHICAL METHOD OF OBTAINING TRUE AVERAGE)

to obtain a closer average, the "shotgun" method (Fig. 5) was used, plotting total fuel per day to output. Barring some unusual results occurring in the early days of the plant, the average fuel consumption is approximately a straight line within observed limits. From this the average fuel per K. W. H. may be obtained, Fig. 6, and the relation approximates a rectangular hyperbola within normal ranges of load. The upper convex curve, Fig. 6, expresses the kinetic or absolute efficiency[1] of the station, and it is interesting to observe that this

[1]Kinetic Efficiency is defined as $= \frac{\text{Thermal Equivalent of work done}}{\text{Heat in coal}}$

small plant normally operates with an efficiency[1] between 12 and 13% average.

TABLE 2 TYPICAL LOG

GOULD COUPLER COMPANY

DEPEW, N. Y.

GAS POWER HOUSE DAILY STATEMENT FOR SEPTEMBER 26, 1905

TIME	PRODUCERS IN 1 2 3	ENGINES IN 1 2 3	PUMPS IN 1 2 3	STATION WATT-METERS OUTPUT KW	VOLTS	MAX. AMPERES	REMARKS
A. M. 7	△ △	△ △ △	△ △ △	1,459,800	230	1000	
8	| |	| | |	| | |	,300	230	2100	8% over-
9	| |	| | |	| | |	,300	230	2100	load.
10	| |	| | |	| | |	,200	230	2000	
11	| |	| | |	| | |	,300	230	2100	
12	| |	▽ ▽	| | |	,300	230	2100	
P. M. 1	| |	△ △	| | |	,100	230	2000	
2	| |	| |	| | |	,300	230	2100	
3	| |	| |	| | |	,200	230	2000	
4	| |	| |	| | |	,300	230	2000	
5	| |	| |	| | |	,300	230	2000	Full Load
6	| |	| |	| | |	,200	230	1800	about
7	| |	| |	| | |	,250	230	1700	1950
8	| |	| |	| | |	,300	230	1900	amperes
9	| |	| |	| | |	,300	230	1900	
10	| |	| |	| | |	,300	230	1800	
11	| |	| |	| | |	,300	230	1900	
12	| |	| ▽	| | |	,300	230	1900	
A. M. 1	| |	| △	| | |	,150	230	1100	
2	| |	| |	| | |	,300	230	1900	
3	| |	| |	| | |	,350	230	1800	
4	| |	| |	| | |	,300	230	1800	
5	| |	| |	| | |	,300	230	1900	
6	▽ ▽	▽ ▽ ▽	▽ ▽ ▽	,250	230	1700	

Day Engineer, ... Hanley
" Helper, ... Young
" Producer Man, ... Benarak
" " " .... Lea
Night Engineer, ... Lowe
" Helper, ... Runer
" Producer Man, Smith
" " " ——

METER READINGS:

6.00 p. m. 1,462,600
Previous 1,459,700
Output 2,900
Coal, 6,000; Coke, ——
Rate 2.06 lbs. per K. W. H.

6.00 a. m., ... 1,466,000
Previous 1,462,600
Output 3,400
Coal, 6,300; Coke, ——.
Rate, 1.85 lbs. per K. W. H.

[1]Since the above observations were made the plant has been giving much better efficiency, the coal consumption averaging 1.8 per kw. h. with an 85% loading factor. This corresponds to a plant efficiency of over 15.4 at the engine shaft or, 14% at the switchboard. Several runs averaging 1.55 lbs per kw. are recorded, equivalent to a plant efficiency of 17.7% at the shaft, of 16.3% at the switch board.

TABLE 3 OPERATING DATA

450 K. W. Producer Gas Power Plant

DATE SEPT. '05	ENGINE HOURS RUN	% FULL DAY RUN	OUTPUT K. W. H.	LOAD—K. W. AVG.	LOAD—K. W. RATED	STATION LOADING FACTOR*	FUEL USED	COAL PER K. W. H.	COAL PER B.H.P.HR
20	71	98⅔	4850	202	450	45	11,100	2.29	—
21	65½	91	5275	220	450	49	11,400	2.16	—
22	70	97½	6550	273	450	61	12,700	1.93	—
23	45½	63½	4025	188	450	41.7	8,800	2.18	—
24 Sun	24	33⅓	2250	187.5	450	41.6	†6,600	†2.93	—
25	70½	98	6400	267	450	59	12,000	1.87	—
26	69½	97	6300	263	450	58	12,300	1.95	—
27	70½	98	6700	279	450	62	12,600	1.88	—
28	72	100	6700	279	450	62	12,900	1.92	—
29	70½	98	6600	275	450	61	12,900	1.95	—
Avg.	63	87½	5565	243.4	450	54	11,330	2.04	1.44

Westinghouse Vertical 3 Cylinder Engines—Loomis-Pettibone Producers.
*Loading Factor = % continuous generating capacity.
†Includes extra coke used on Sunday for starting new fires.

12 From the above data and the measured efficiency of the gas engine, the efficiency of the producer plant may be roughly estimated. Assuming 50% loading factor, the average plant efficiency is 12%; as the efficiency of the engines is approximately 17% at this load (see Fig. 9), the producer plant operates at an efficiency of slightly above 70%. With higher loading factor—75%, the plant efficiency is 13% average, engines 20% and producers 65%. During an especially good day's run, as on September 27, the efficiencies were as follows: plant 15%, engines 21%, producers 71.5%. These results indicate that the producer plant is, from an everyday operative standpoint, fully as efficient as a high grade boiler plant and frequently more so. It is certainly not more difficult to handle.

13 As to the cost of power the following analysis reveals a total cost of well under one cent per K. W. H., including fixed as well as operating charges. At normal prices, coal[1] costs $2.30 per ton. Assuming an average daily outputs of 5000 to 10,000 K. W. H. representing the probable minimum and maximum for full working days, and adding the fixed or capital charges amounting to about 9% on $91,650 (or $81,000 excluding the battery), the distribution of cost items is substantially that given on the following page.

[1]Buffalo, Rochester and Pittsburg Bituminous run of mine, 13,500 B. T. U. per pound.

APPROXIMATE POWER COSTS

	Minimum	Normal	Maximum
Output—K. W. H. per day	5000	8000	10,000
Fuel—Cents per K. W. H	0.25	0.22	0.20
Labor—Cents per K. W. H	0.28	0.17	0.14
[1]Supplies and Repairs (estimated) c. K. W. H.	0.17	0.13	0.11
Operating Costs, c. K. W. H.	0.70	0.52	0.45
Fixed Charges	0.45	0.28	0.22
Total Costs, c. K. W. H.	1.15	0.80	0.67

14 In order to emphasize the effect of loading factor Fig. 7 has been prepared showing the relation of both capital and operating costs to the station loading factor, the former plotted above and the latter below, the X axis. Total cost of power is given by the total ordinate. Observe the rapid change in costs on light loading, especially of fixed charges. Coal, on the other hand, remains fairly constant; labor a constant charge, increases rapidly on light loads, and supplies and repairs a variable charge, less rapidly. The importance of loading factor is well brought out by this diagram; *e. g.*, the total cost of power is halved by increasing the loading factor from 24 to 55%. An industrial or railway power plant usually operates on about the latter figure, a moderate sized lighting plant on the former; hence, the danger of indiscriminate comparisons of operating costs in power plant work.

15 Considering that the results above enumerated have been obtained from a comparatively small plant, operating under conditions by no means conducive to the attainment of the highest economies, the Depew plant offers a striking object lesson that should not fail of appreciation among engineers confronted with similar problems; and much credit is due the Gould Company through its consulting engineer, Mr. W. E. Winship, and its resident manager, Mr. J. O. Gould, for early appreciation of the advantages of gas power and efficient management of the Depew property. The author begs to acknowledge their courtesy and assistance in placing cost and operating data at his disposal.

[1]These charges are estimated owing to absence of more accurate data and the comparatively short time plant has been in operation. Assume 25% of total power costs at 50% L. F., hence, the estimate is conservative.

It should be noted that were the plant to operate regularly at the lower load factors less labor and supplies would be required and the light load costs would be correspondingly reduced. The curves Fig. 7 are based on full plant in service operating continuously.

DESCRIPTIVE SECTION

GROUNDS AND BUILDINGS

16 An excellent location has been chosen for the power plant adjacent to the Lackawanna R. R. main line. In the intervening space is a large semi-circular reservoir, serving the twofold purpose of a cooling pond and reservoir for general fire protection, and incidentally enhancing the attractiveness of the property to no small degree.

17 For convenience to coal supply the producer house is located several hundred feet in the rear, adjacent to a large metallurgical producer plant serving the steel furnaces. A single coal handling system thus serves both producer equipments. This arrangement of buildings emphasizes the possibilities in gas power work of separating, at any distance, the producer and gas engine parts of a power plant for operative, or other, convenience.

18 Brick, steel and concrete are largely used as building material. In the producer house where the fire hazard is, of course, considerable no wood at all is employed, walls and roof being constructed of corrugated iron and charging floor of boiler plate. Spacious monitors in both buildings provide the very necessary ventilation and light.

GENERATING PLANT

19 Considerations of operating economy largely influenced the choice of gas engines for this plant where steam coal costs from $2.25 to $2.40 per ton, and gas coal about the same. At this price it was estimated that, although the difference between the steam and gas was small on half day working, for a 24 hour day the latter's advantage was decisive.

20 The installation of three units of similar size and identical construction wisely avoided the duplication of parts which two or three sizes of engines would have occasioned. By the use of direct connected units a very compact power house arrangement has resulted, the total floor area per kw. being 6.1 square feet, and the net area of each unit with six foot passageways 2.9 square feet per kw.

21 The efficiency of these engines as heat engines is well indicated by the appended results of tests[1] shown in the accompanying Table

[1]Made at the builder's works on natural gas which was at that time the only fuel available for testing purposes. As engines for producer gas are usually constructed for somewhat higher compression than those operating on illuminating or natural gas, their efficiency would presumably be slightly better on natural than on producer gas fuel; yet for commercial work a difference of 15 pounds in compression would scarcely be appreciable.

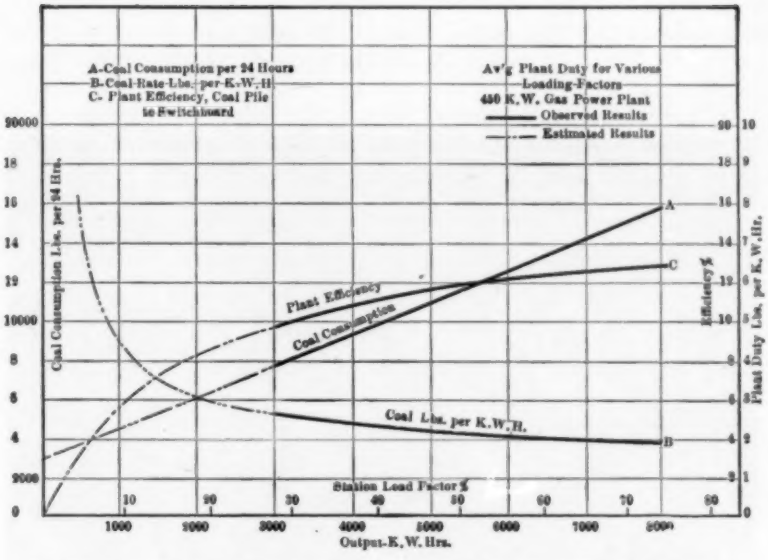

A-Coal Consumption per 24 Hours
B-Coal Rate-Lbs. per K.W.H
C- Plant Efficiency, Coal Pile to Switchboard
Av'g Plant Duty for Various Loading Factors
400 K.W. Gas Power Plant
Observed Results
Estimated Results
Coal Consumption Lbs. per 24 Hrs.
Plant Efficiency %
Plant Duty Lbs. per K.W.Hr.
Plant Efficiency
Coal Consumption
Coal Lbs. per K.W.H.
Station Load Factor %
Output-K.W. Hrs.

FIG. 6 AVERAGE PLANT DUTY AT VARIOUS LOADING FACTORS

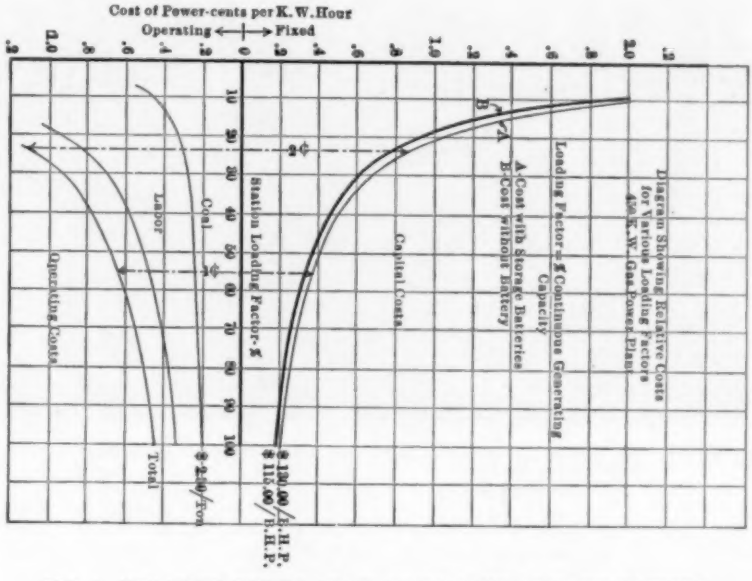


FIG. 7 RELATIVE POWER COSTS AT VARIOUS LOADING FACTORS

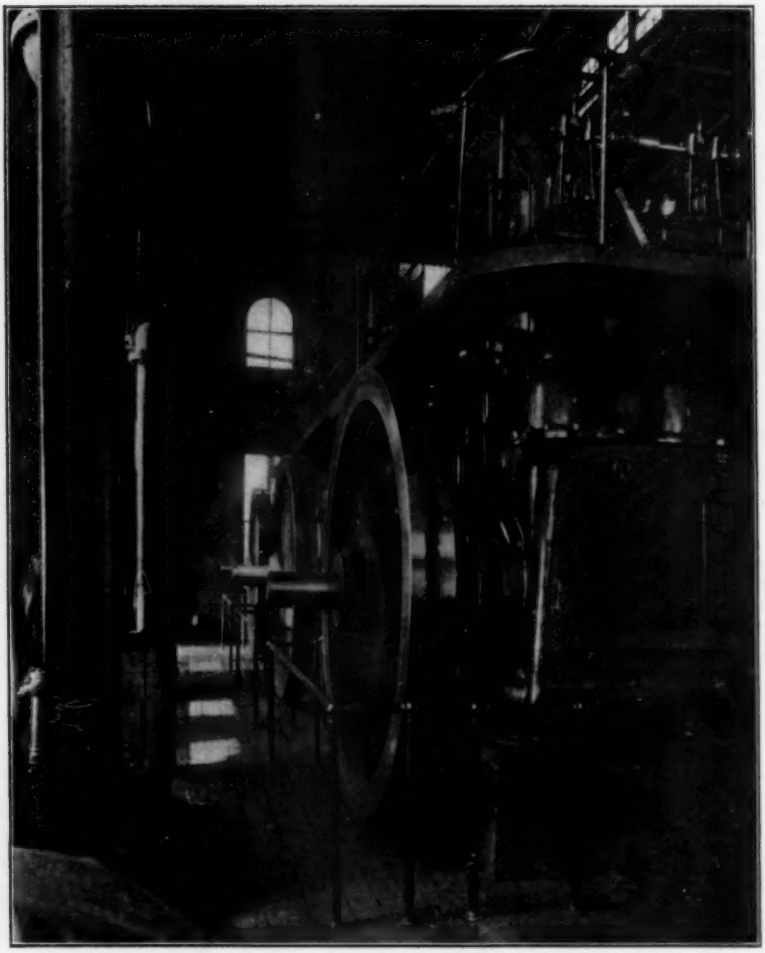


FIG. 8 ENGINE ROOM SHOWING GAS PIPING AND POSITION GAS REGULATORS

4 and diagram Fig. 9. In the latter the upper concave curve represents the gas consumption per B. H. P. under different loads and the convex curve, the kinetic or absolute efficiency.

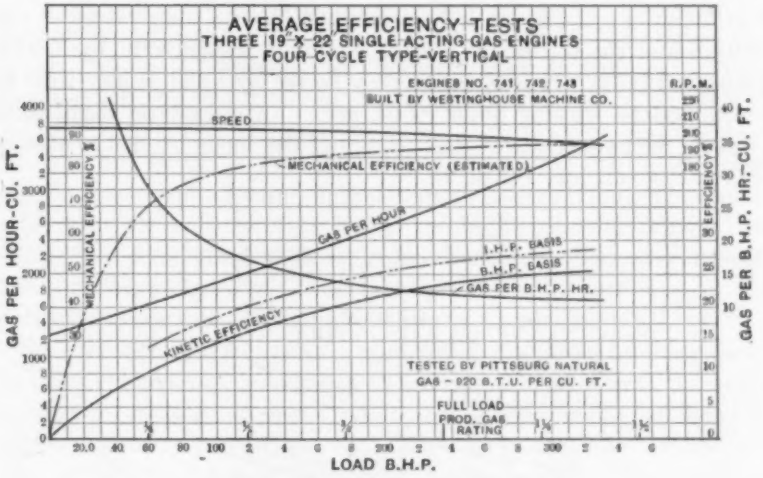


FIG. 9 AVERAGE EFFICIENCY TESTS

TABLE 4 ENGINE EFFICIENCY

AVERAGE OF TESTS

Three 19″ x 22″ Single Acting Four Cycle Gas Engines

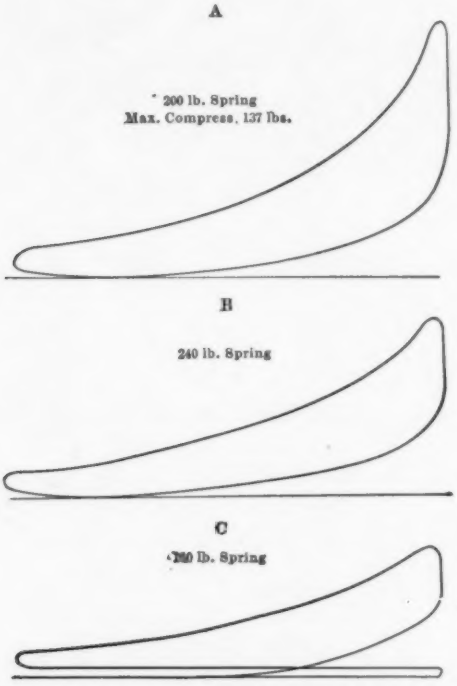
Engines Nos. 741, 742, 743

LOAD	OVER	FULL	HALF	REMARKS
Brake horse power	325.3	239	121.3	By Prony brake.
Speed R. P. M.....	198	203	206.3	By counter.
Gas per hour	3,547	2,840	1,985	Corrected to 62° F. 30″ Hg.
Gas per B. H. P. hour..	10.9	11.87	16.36	Corrected gas—no load—1250 ft. per hr.
Heat value gas*	920	920	920	Effective B. T. U. per cu. ft.
B. T. U. per B. H. P. Hr.	10,030	10,910	15,050	
Brake kinetic efficiency..	25.37	23.32	16.9	B. H. P. basis.
Mechanical efficiency ...	89	87.5	82.5	Estimated.
Indicated kinetic efficiency.....	28.5	26.7	20.5	I. H. P. basis.
Speed variation-max ...	4.2%			No load speed 206.6.
" " No-full load		1.8%		Average speed.
" " No-half "			0.7 %	
Per cent full rating.....	138.4%	101.6%	51.6 %	On producer gas.

*Pittsburg Natural Gas—Junker Calorimeter.
Engines rated 235 B. H. P. on 130 B. T. U Producer Gas.

The ability to convert into useful power over 25% of the effective heat in the gas gives evidence of high efficiency.

22 These engines operate on the four stroke cycle involving constant quality of mixture and throttling governing. The actual proportioning of gas and air is accomplished by two plug valves at the bottom and the top of the mixing chamber, respectively, each with graduated index. These valves may be set by hand at any time to accommodate varying qualities of gas. An automatic diaphragm pressure regulator reduces the pressure of the incoming gas to atmosphere at the engine, Fig. 8.



FIGS. 10a, 10b AND 10c TYPICAL INDICATOR CARDS
CORRESPONDING TO LOADS IN TABLE 4

ENGINE AUXILIARIES

23 A most important factor in the successful operation of the engines is the ignition apparatus. For increased security each igniter plug has two sets of points, each set independently connected. Should one set of points, through any cause, become unfit for use, a small double throw switch may be reversed, thus turning the ignition

current through the other points. In addition, three independent sources of current have been provided, all of the apparatus being contained in a central ignition cabinet. For starting, one of two 8-volt storage batteries is used. For running, a small ½ kw. motor generator unit is used delivering 110 volt current to the igniters through incandescent lamps, which furnish a valuable "tell-tale" for "open circuits," "grounded igniters," or "hanging fire" of igniters. These two sets of storage batteries are charged alternately through a bank of lamps from the motor generator or from the main station bus bar one or the other set being always available in an emergency. By means of small double pole switches at the igniter cabinets, throwing over from the low to the high tension system may be instantly accomplished without in the least disturbing the engines. The ignition problem has thus been handled with great care in the provision of six individual combinations of current supply.

24 Starting of the engines is accomplished as usual by compressed air drawn from a pipe connection to a compressed air line in the works or from the relay compressor. Although only 90 to 100 pounds pressure is ordinarily carried; yet the engines may readily be brought up, cold, to full running speed, within 30 to 40 seconds. With higher air pressurea vailable, starting may be accomplished in even less time, as the mixture ignites more readily when quickly compressed, owing to the smaller opportunity for the dissipation of internal heat.

25 Another important part of the plant equipment is the circulating water system for cooling jackets, combustion chambers and exhaust valves. Motor-driven rotary pumps are ideally suited to this work on account of the moderate pressure required—about 25 pounds per square inch. Two of these pumps (one for relay) serve the engine plant while a third, of the two-stage turbine type, serves the gas producer scrubber in which a higher pressure is desirable. Although each pump is driven by a 15 H. P. motor, the power ordinarily required is considerably less than this, especially in moderate and cold weather when the quantity of water supplied to the engines may be largely reduced by throttling the pump outlets.

COOLING RESERVOIR

26 Previous mention has been made of a cooling pond. This has a normal depth of 10 feet with a total capacity of about 1,000,000 gallons. It is approximately semi-circular in plan and is divided radially into two compartments to separate the comparatively dirty scrubber water from the pure jacket water. All make-up water used at

the plant is delivered to the pure water pond through the engine jackets.[1] The excess overflows into the scrubber water pond and thence to the sewer. Cooling water for the engine is drawn from near the bottom through a screen house, while the hot jacket water is returned to the surface of the pond, about 150 feet distant. During the progress of the water from inlet to outlet enough heat is dissipated to the earth and atmosphere to reduce the outlet water to the proper temperature. During periods of extreme heat and humidity when the cooling process is retarded, a larger quantity of water may be sent through the jackets to compensate for the lesser difference in temperature. For this the rotary pumps are well suited. In September, 1905, the following observations were made:

Jacket water entering pond	99.3° Fahr.
Surface of water near inlet	78.8° "
Air	73.8° "
Bottom of reservoir near outlet	76.1° "
Surface of reservoir near outlet	77.9° "
Average load on plant	310 kw. = 500 H. P.

Thus on a fair day with practically seven-tenths load on the plant there was a difference in temperature of 1.8° Fahr. in eight feet depth of water, 0.9° Fahr. difference between the temperature of reservoir at intake and outlet, 4.6° Fahr. difference between air and mean reservoir temperature and 23.2° Fahr. total cooling.[2] Apparently considerable cooling took place through the transmission of heat through the bottom of the reservoir.

PIPING

27 Some trouble has been experienced with the gas gates, due apparently to cumulative deposits of carbon, and frequently it becomes impossible to seat the valves tight. In work of this class it would seem that a parallel seated quick closing gate would be best suited, being self-cleaning, and the gas could be cut off almost instantly in case of emergency.

28 The engine exhausts all discharge into a cast iron header running beneath the floor to a concrete exhaust well outside, serving as a muffler. Unfortunately, it is impossible to cool these exhausts by

[1] It is of interest that nearly all of this "make-up" water is supplied from roof drainage. City water being comparatively expensive (10–15 c. per 1000 gallons) and this utilization of roofage insures an important economy. The pond also supplies feed water for some steam boilers.

[2] As there was no overflow from the power pond at the time this cooling was effected from about 7300 sq. ft. of exposed water surface.

water sprays on account of the large amount of SO_2 in the gas. If water were used, as is the practice with natural gas, the piping would soon be destroyed by corrosion. As some 30% of the total heat value of the gas is lost in the exhaust, radiation is a somewhat disagreeable feature, especially in warm weather. This trouble may, however, be obviated by enclosing the piping in a concentric sheet metal casing through which rapid circulation may be maintained from basement to ventilators in the roof. It is also possible that a reinforced concrete duct might be employed for exhaust piping, molded in sections, cemented in position and encased in sheet steel. If rigidly supported this material should easily withstand both the heat and corrosive action of the exhaust vapors when water cooled in the usual manner.

29 The muffler well is, to be sure, a common arrangement in gas power plants, but most certainly could be improved upon. First,the noxious products of combustion rising from the pit, although located in the open, are driven directly into the engine room during certain prevailing winds to the great discomfort of the operators. Second, if the exhaust pit is carried to any considerable distance from the power house, a serious back pressure is imposed on the engines owing to the friction of the high pressure exhausts on the internal surface of the main. Usually the well is located close to the building with a short standpipe. This outlet is almost invariably too small, resulting again in serious back pressure from throttling. And it usually occurs that sooner or later the structure is dismantled by sudden pressures due to delayed combustion or other causes. A more logical arrangement would seem to be as follows: (1) A brick or concrete exhaust well of large dimensions built next to the power house foundation wall and loosely filled with large broken rock, (2) a brick stack extending to the roof and built into the building structure integral with pilasters thus taking advantage of the reinforcement offered by the steel skeleton of the building, (3) simple sheet steel flap doors or louvres inserted in the roof of the exhaust pit and at two or three points in the chimney to relieve occasional local pressures. In this manner the noxious gases are easily taken care of by a flue of cheap construction, agreeable appearance, and ample capacity for any contingency.

30 Water cooling piping is simple, a manifold supplying all three cylinder jackets in parallel. Water enters at the bottom of the jacket, emerging from the top. A small pipe loop at the discharge end of the upper manifold with vent cock at the top to break the vacuum serves to prevent the syphoning effect which under certain conditions might pull all the water out of the jackets, leaving nothing but steam. This vent is useful as a tell-tale showing stoppage of jacket water supply.

31 In cooling the exhaust valves a fairly constant supply is desirable, irrespective of the load. The arrangement shown in the sketch, Fig. 11, is therefore employed by which the jacket water may be throttled as much as desirable, while constant head is maintained at the exhaust valves.

OPERATION OF ENGINES

32 Four men, two to a shift, operate the generating plant, the oilers and the two engineers, being formerly steam engine operators. The personal attitude of the Chief Engineer toward the gas engine plant well refutes the frequent argument that gas engines require more

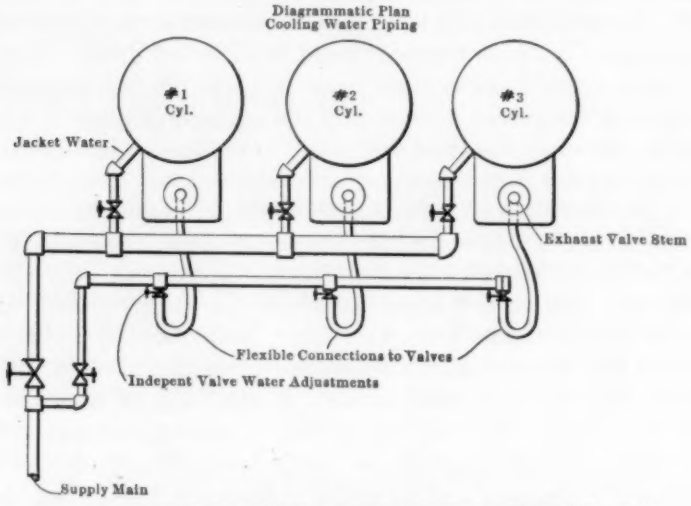


FIG. 11 PLAN COOLING WATER PIPING FOR CYLINDERS AND EXHAUST VALVES

skilled operators than steam engines; the plant not only requires less actual manual labor to keep in running order, but it is fully as responsive to good handling as a steam plant. All things considered, he "would regret to go back to steam." The fact that the engines are often left in charge of, and operated by, the oilers illustrates the point in view.

33 While the producer is undergoing renovation on Sundays, the engines are also inspected in rotation, mixing valves flushed down with gasolene to remove lampblack deposits (likewise cylinders, now and then to keep the packing rings free), valves are ground in and igniters replaced when necessary, jacket deposits cleaned out when obstructed to any extent, and the engines generally adjusted. Reducing valves

are also cleaned, at intervals, from carbon deposits. Practically the only trouble experienced thus far has been the occasional cutting of an exhaust valve, presumably due to cumulative carbon deposits on the valve seats. The lampblack has also occasioned some difficulty in lubricating valve stems. Igniters, of course, wear down gradually, but extras are always kept on hand and repointed as fast as necessary. Usually one igniter will last from six to nine months without repointing. Since commencing normal operation engine repairs have been confined to these two items and are comparatively light considering the conditions of operation. Very little trouble has been experienced with lubrication, as the main working parts are automatically supplied by the splashing of oil. All oil used in outer bearings returns to the crank case to make up that lost through evaporation. When the oil reaches too high a level the excess is drawn off, filtered and used over in the bearings.

34 In starting and stopping the engines the attendants have acquired so much skill that the barring lever is seldom used. By manipulating the air valves just as the engine comes to rest it is not difficult to bring the air cams in starting position so that no time need be lost in barring the engine around to the position for starting.

PRODUCER PLANT

35 A notable feature of the producer plant is that it is capable of gasifying bituminous coals without making quantities of tar. The process is intermittent, embodying the now more or less well known system of passing the green hydrocarbon distillates through a secondary fire bed which has previously been brought up to the proper temperature by blasting with air. Since the plant was started, a fair grade of soft coal (B. R. & P. run of mine) has been used, averaging about 13,500 B. t. u. per pound. Although this coal presumably contains 35% of volatile, tar destruction in the producers is complete, but at the same time a considerable quantity of lampblack has resulted which has made it necessary to devise special means to handle this by-product. No attempt has been made to market it, as some is used in the preparation of paints for castings, etc.

36 Straight producer gas is not made directly, but water gas and air gas are made at alternate intervals of varying duration according to richness of the gas desired. In metallurgical plants the two gaseous products of the system are often handled separately, the water gas being used for heating furnaces on account of its high flame temperature and the blast gas in gas engines for power purposes. And it is an interesting fact that, although this blast gas would be absolutely

unfit for any other use on account of its comparatively low calorific value—from 80 to 90 B. t. u. per cu. ft.—yet it is quite suitable for gas engine work, in that it is not at all snappy (as is water gas) and, therefore, permits of higher compression. At Depew the two gases are mixed in a single holder in the proportion generated.

37 In this system two producers constitute a unit. Usually it is desirable to have a separate unit on hand for relay purposes. Here this was especially necessary in order to provide an opportunity for freeing the producer from clinker formed during the week's run. At Depew a novel arrangement was first employed, in the form of a clover leaf with three producers united at top and bottom by T pipe connection with the necessary water cooled valves. It was then possible to renew one producer fire per week in rotation, and at the same time save the cost of a fourth producer to complete the duplicate unit. Through no fault of this arrangement, however, it was not an entire success, owing to the difficulty in preventing the leakage of water gas into the idle producer through the valves. This difficulty has now been overcome and a complete relay plant, including scrubbing equipment, is provided in the adjoining producer building with sensibly better results than before.

PRODUCER AUXILIARIES

38 A feature of the system is that all steam required is generated entirely from the sensible heat of the gases coming from the producers which would otherwise be wasted in cooling water.[1] With the high "heats" necessary in the intermittent process, this represents an important saving. The boiler, however, requires weekly cleaning.

39 The proper cleaning of the gas is a difficult problem, owing to the fact that lampblack does not easily adhere to a wetted surface as does ordinary cinder dust. In this plant the gas first passes upward through a wet scrubber containing several tiers of small coke constantly wetted down by water sprays. A thin layer of dry excelsior is also used in the top tiers. Emerging from the wet scrubber, the gas enters two large dry scrubbers filled with several tiers of excelsior and piped up in parallel so that the velocity of the gas is not only reduced, but also the amount of gas handled by each drier. Finally, an engine driven Root's exhauster delivers the gas to the holder.

40 The various valve movements are handled mechanically by

[1]This condition however obtains only when the plant is heavily loaded. Running light it would be difficult to make sufficient steam to operate the producer auxiliaries. An air auxiliary boiler would have to be drawn upon.

rack gears with operating wheels conveniently placed on the level of the operating floor.

PRODUCER OPERATION

41 The present method of operating the producer plant requires an air gas run of 10 to 15 minutes, according to the demand for gas at the power plant, and a water gas run from one-half to three-quarters of a minute, the resulting mixture being well suited to power work.

42 Frequent testing of the quality of the gas made is not now practiced on account of its uniformity under the present operating condition. The holder, of course, greatly assists in insuring uniform gas at the engines. At the same time it provides sufficient capacity for operating one unit at full load for about three-quarters of an hour; the full plant in inversely proportionate time. Storage capacity is particularly valuable when a new fire is being put into service. This is usually done during the noon hour when the load is light, so that a lowering of the heat value of the gas is relatively unimportant.

43 In ordinary operation it is a simple matter to observe the quality of gas by means of two sampling flames always in view of the operators. One consumes gas from the holder; the other consumes freshly made gases as they leave the dry scrubber. Any irregularities may then be readily detected. Calorimeter tests show the gas as made at the present time to average slightly above 100 B. t. u. per cu. ft. (see Table 5). This comparatively low heat value is, of course, due to the preponderating period of blasting. With the rate of water gas mixing practically fixed, the only variable factor to compensate for varying demands for gas is the rate of blasting; hence, there is a long and subdued air gas run with a rapid but short run on water gas. During the second test (Table 5) the gas consumption was observed to be about 1100 cu. ft. per minute at a load of 395 kw. This is equivalent to 167 cu. ft. per K. W. H. at seven-eighths load on the generating units, and represents approximately a duty of 16,700 B. t. u. per K. W. H., or a little over 11,000 B. t. u. per B. H. P. hour.

44 Coal consumption is determined by direct weighing in the producer house. Each shift weighs up enough coal at the start to run the plant through twelve hours; should there be a surplus at the end, it is weighed back and charged to the next shift, thus making each shift responsible for all fuel used during their run.

45 The entire producer plant is operated throughout the week by four men, two to a shift, with some additional labor on Sundays for

cleaning. All the attendants were unskilled foreigners before taking up the producer work. During a half day shut down of the plant on Sundays, all renovating of the producer equipment is done; boiler tubes are cleaned, wet scrubber washed down, the excelsior in the dry scrubbers taken out and shaken free from lampblack, gas mains flushed out and a new fire started in the idle producer. At the same time, another producer is taken out of service, fires are drawn, and during the week, after it has had an opportunity to cool off, the hard

TABLE 5 CHARACTERISTICS OF POWER GAS

TYPICAL ANALYSIS

Date, June, 1905	20th	21st	23d
Number of hours test	3	10	10
Intervals of tests (minutes)	15	15	15
Minimum calorific value	98	91	91
Maximum " "	113	110	104
Average calorific value	105	100	100
Maximum variation from avg.	7½%	10%	9%

DATE	H	CO	CH_4	O	CO_2	N
Sept. 9, 1905	9.50	21.0	1.9	0.6	6.5	60.9
Sept. 12, 1905	10.13	22.8	2.2	0.4	5.6	58.9

clinker, which adheres to the lining, is broken off. For the starting layer of a new fire bed, coke is used to the extent of some 3000 pounds per producer, a sufficient quantity to affect the coal consumption of the succeeding day. If allowed to form to any extent, clinker constitutes a frequent source of trouble in operating the plant, and it is important that the selection of coal be made with this in view. With fires fairly free from clinker the suction required for blasting may be only eight to ten inches of water, but with fires badly clinkered it may run up to 25 inches. With 10 to 15 inches drop in the scrubbers, this imposes from 30 to 40 inches suction on the exhauster, thus largely increasing its steam consumption.

A HIGH DUTY AIR COMPRESSOR

By O. P. Hood, Houghton, Michigan
Member of the Society

1 Large steam engines of exceptional performance have usually been connected with pumping machinery, the definite load removing some of the limitations imposed upon the designer of engines for general service. This characteristic of nearly uniform work performed per stroke is possessed also by machines for compressing air and the needs of a large mine are such as to require units for this purpose of large size. In the copper country of Michigan several such compressed air plants exceed 1000 H. P. each and there is one about 5000 H. P. Fuel is confined to the better grades of bituminous coal, worth in the hands of the fireman from $3 to $4 per ton so that economy in its use seems desirable. These facts have led some managers to install high duty machinery, and it is the purpose of this paper to report the results found in a test of a high duty air compressor installed at the Champion copper mine at Painesdale, Mich.

2 At the time of selection of this machinery Dr. L. L. Hubbard was general manager and Mr. F. W. O'Neil (Junior Member) was chief engineer. The Nordberg Manufacturing Company of Milwaukee, Wis., proposed an engine designed to use steam at 300 pounds pressure equipped with a regenerative feed water heating system.[1]

It was guaranteed that this engine should develop 180,000,000 foot pounds of work in the steam cylinders for each one million heat units used and should compress 9000 cubic feet of air per minute to a pressure of 80 pounds gage, at 76 r. p. m. This guarantee was accompanied with a bonus and forfeit clause, the amount to depend upon the results of duty trials of the engine. Geary water tube boilers were installed and practically no difficulty was experienced with the installation until at pressures above 250 pounds, when there appeared boiler troubles which made it necessary to run the plant at the

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[1]Transactions, Vol. 21, p. 181

reduced pressure of 250 pounds. Under these conditions the original contract could not be carried out, but it was desired by Mr. F. W. Denton, General Manager of the Copper Range Consolidated Company, operating this mine, to discover the actual performance of this engine under the daily running conditions of reduced boiler and air pressure and at a speed about three-fourths of that contemplated in the guarantee but sufficient for the present maximum needs of the mine. The machine had been in commission for about 17 months, was in good order, and no changes of adjustments were made for the test. The test did not include the performance of the boilers.

3 The boiler plant consists of three "Geary" water tube boilers, each of brick, and set over 42 square feet of grate area.

4 Each boiler is hand fired, is credited with 2068 square feet of heating surface and has 112 four-inch tubes 16′ long connecting front and rear water legs 11½″ wide. There are no baffles in the double drums. Gases pass through a Green economizer and motor driven fans to a short stack. Standard hydraulic pipe fittings are used.

DESCRIPTION OF THE ENGINE

5 The machine consists of four horizontal engines placed side by side, numbered for convenience 1, 2, 3, and 4. The high pressure engine, No. 1, has a cylinder diameter of 14.5″ with poppet valves connected to a governor, limiting the speed and also the maximum air pressure produced. No. 4 is the low pressure engine with a 54″ cylinder. The intermediate engines, No. 2 and No. 3, have cylinders 22″ and 38″ in diameter and all of these have Corliss and cut off adjustable valves, but not connected to the governor. The several cranks pass a dead center in the following order; No. 1 outer center, No. 3 inner, No. 4 inner, and No. 2 outer dead center.

6 The main shaft carries three fly wheels, the usual eccentrics for the Corliss valve motions and for the mechanically operated air valves. It also drives an offset crank on the high pressure end to actuate poppet valves, and a cranked shaft from the low pressure end to operate auxiliaries and the special valve in the low pressure heads. Below and between the cylinders reheating receivers are placed, each supplying steam to the cylinder, the jacketed heads, and the bodies of the next succeeding cylinder. Each head of the low pressure cylinder is provided with a rotating disk valve, driven from the main shaft, the function of which is to abstract steam during expansion. Steam is supplied through 90′ of 5″ double extra heavy pipe including a "Sweet" special separator 16″ in diameter and 42″ long.

Time	No. of Card	No 1 Engine H.P. - Spring - 150 Lb.								No 2 1st Intermediate. - Spring 80 Lb.							
		Head End - K = 1.1429				Crank End - K = 1.0817				Head End K = 2.62633				Crank End - K = 2.56483			
		Area	Length	M.E.P	I.H.P.	Area	Length	M.E.P	I.H.P.	Area	Length	M.E.P	I.H.P.	Area	Length	M.E.P	I.H.P.
AM 7:15	1	2.06	3.72	83.1	94.98	2.00	3.77	79.6	86.06	2.37	3.78	50.2	131.84				
7:45	2									2.32	3.78	49.1	128.95	2.20	3.85	45.7	117.20
8:15	3	2.10	3.70	85.2	97.38	1.98	3.70	80.2	86.71	2.35	3.77	49.9	131.05	2.24	3.83	46.8	120.02
8:45	4	2.00	3.69	81.3	92.92	1.92	3.68	78.3	84.66					2.31	3.84	48.1	123.36
9:15	5					1.98	3.73	79.7	86.17	2.40	3.80	50.5	132.62	2.29	3.84	47.7	122.33
9:45	6									2.42	3.78	51.2	134.46	2.31	3.84	48.1	123.36
10:15	7													2.44	3.84	50.8	130.28
10:45	8	1.99	3.70	80.7	92.23	1.91	3.70	77.4	83.68					2.45	3.84	51.1	131.05
11:15	9	2.03	3.71	82.1	93.83	1.97	3.69	80.1	86.60	2.39	3.80	50.3	132.10	2.36	3.85	49.1	125.92
11:45	10	2.07	3.72	83.4	95.32	2.00	3.70	81.1	87.69	2.38	3.79	50.2	131.84	2.34	3.85	48.6	124.64
12:15	11	2.12	3.72	85.5	97.72	2.07	3.70	84.0	90.82	2.35	3.79	49.6	130.26	2.37	3.85	49.2	126.17
12:45	12	2.04	3.72	82.3	94.06	1.94	3.67	79.3	85.74	2.34	3.80	49.3	129.48	2.40	3.85	49.9	127.97
1:15	13	2.03	3.72	81.8	93.49	1.98	3.69	80.5	87.44	2.39	3.78	50.6	132.89	2.39	3.82	50.1	128.48
1:45	14	2.12	3.72	85.5	97.72	2.02	3.69	82.1	88.77	2.42	3.80	50.9	133.68	2.35	3.80	49.5	126.95
2:15	15									2.37	3.75	50.6	132.89	2.37	3.82	49.6	127.20
2:45	16	2.00	3.73	80.4	91.89	1.96	3.72	79.0	85.41	2.32	3.77	49.2	129.22	2.32	3.80	48.9	125.41
3:15	17	2.01	3.72	81.1	92.69	1.95	3.68	79.5	85.96	2.32	3.77	49.2	129.22	2.36	3.81	49.5	126.95
3:45	18	2.04	3.73	82.0	93.72	2.05	3.72	82.7	89.42	2.32	3.78	49.1	128.95	2.35	3.80	49.5	126.95
4:15	19	1.99	3.71	80.5	92.00	1.96	3.69	79.6	86.06	2.28	3.78	48.3	126.85	2.29	3.82	48.0	123.10
4:45	20	2.06	3.72	83.1	94.98	2.02	3.68	82.4	89.09	2.37	3.77	50.3	132.10	2.35	3.81	49.4	126.69
	Totals				1414.93				1389.88				2220.90				2384.03
	Average				94.33				86.867				131.08				125.47
	Corrected H.P.				94.47				87.00				131.29				125.67

FIG. 1 INDICATED HORSE

Time	No. of Card	No 1 Air - Spring - 16 Lb.								No 2							
		Head End - K = 1.745034				Crank End - K = 1.744088				Head End - Spring 40 - K = 2.82482				Crank End Sp. 60 - K = 2.8153			
		Area	Length	M.E.P	I.H.P	Area	Length	M.E.P.	I.H.P	Area	Length	M.E.P	I.H.P	Area	Length	M.E.P	I.H.P
AM 7:15	1	3.49	3.91	14.28	106.39	3.66	3.89	15.01	111.69	3.72	3.90	38.15	107.77	2.45	3.86	38.10	107.26
7:45	2									3.87	3.86	40.1	113.27	2.55	3.90	39.25	110.50
8:15	3	3.50	3.93	14.25	106.17	3.61	3.89	14.85	110.50	3.88	3.90	39.8	112.43	2.58	3.89	39.80	112.05
8:45	4	3.50	3.92	14.28	106.39	3.70	3.93	15.07	112.13	3.94	3.86	39.8	112.43	2.53	3.87	39.23	110.45
9:15	5	3.59	3.92	14.65	109.15	3.72	3.89	15.29	113.77	3.77	3.88	38.9	109.89	2.56	3.88	39.62	111.54
9:45	6	3.57	3.92	14.57	108.55	3.70	3.87	15.22	113.25	3.84	3.88	39.6	111.86	2.55	3.85	39.77	111.96
10:15	7	3.53	3.92	14.41	107.36	3.68	3.90	15.11	112.43	3.80	3.88	39.2	110.73	2.55	3.86	39.65	111.62
10:45	8	3.50	3.94	14.21	105.87	3.66	3.90	15.01	111.69	3.86	3.90	39.6	111.86	2.53	3.86	39.34	110.76
11:15	9	3.48	3.89	14.32	106.69	3.62	3.90	14.85	110.50								
11:45	10	3.52	3.93	14.34	106.84	3.64	3.88	15.02	111.76	3.88	3.90	39.8	112.43	2.59	3.87	40.15	113.03
12:15	11	3.56	3.89	14.65	109.15	3.70	3.87	15.30	113.84	3.77	3.90	38.7	109.31	2.48	3.89	38.25	107.69
12:45	12	3.49	3.91	14.28	106.39	3.62	3.89	14.88	110.72								
1:15	13	3.52	3.87	14.55	108.40	3.67	3.88	15.09	112.28	3.82	3.89	39.3	111.02	2.50	3.85	39.0	109.80
1:45	14	3.55	3.89	14.61	108.85	3.72	3.90	15.26	113.55	3.74	3.79	39.5	111.58	2.45	3.78	38.9	109.51
2:15	15	3.53	3.88	14.56	108.48	3.67	3.88	15.13	112.58	3.80	3.90	38.98	110.11	2.55	3.87	39.55	111.34
2:45	16					3.63	3.88	14.97	111.39	3.84	3.87	39.1	112.15	2.60	3.92	39.8	112.05
3:15	17	3.52	3.88	14.52	108.18	3.68	3.86	15.25	113.47	3.85	3.90	39.5	111.58	2.55	3.88	39.45	111.06
3:45	18	3.55	3.88	14.65	109.15	3.68	3.86	15.25	113.47	3.83	3.89	39.4	111.30	2.51	3.87	38.93	109.60
4:15	19	3.48	3.89	14.31	106.61	3.60	3.86	14.92	111.02	3.78	3.88	38.98	110.11	2.54	3.86	39.50	111.21
4:45	20	3.49	3.89	14.35	106.91	3.61	3.87	14.92	111.02	3.80	3.90	38.98	110.11	2.52	3.85	39.28	110.59
	Totals				1335.53				2131.06				1999.95				1992.01
	Average				107.53				112.16				111.11				110.67
	Corrected H.P.				107.70				112.34				111.28				110.84

FIG. 2 INDICATED HOR

80 Lb.		N° 3 — 2nd Intermediate — Spring - 20 Lb.								N° 4 — L. P. Spring - 10 Lb.								
2.56453		Head End - K = 7.02804				Crank End - K = 7.76633				Head End - K = 15.808				Crank End - K = 15.7462				
P	I.H.P.	Area	Length	M.E.P.	I.H.P.	Area	Length	M.E.P.	I.H.P.	Area	Length	M.E.P.	I.H.P.	Area	Length	M.E.P.	I.H.P.	Totals
		3.32	3.90	17.02	133.23	3.44	3.90	17.65	137.08	3.43	3.95	8.68	137.22	3.29	3.86	8.52	134.16	980.04
7	117.20	3.44	3.90	17.65	138.16	3.51	3.90	18.00	139.79	3.31	3.96	8.36	132.16	3.37	3.89	8.67	136.52	973.98
8	120.02	3.49	3.92	17.80	139.34	3.62	3.90	18.56	144.15	3.43	3.98	8.62	136.26	3.34	3.86	8.66	136.36	991.45
1	123.36	3.61	3.94	18.33	143.49					3.33	3.92	8.50	134.37	3.33	3.84	8.48	133.68	983.72
7	122.33	3.59	3.93	18.27	143.02	3.55	3.92	18.11	140.65	3.32	3.91	8.50	134.37	3.29	3.82	8.61	135.57	989.06
1	123.36	3.48	3.90	17.65	137.73	3.48	3.90	17.85	138.63	3.32	3.90	8.52	134.68	3.32	3.81	8.72	137.31	989.37
8	130.28	3.50	3.92	17.85	137.73	3.37	3.91	17.35	134.75	3.39	3.93	8.63	136.43	3.22	3.83	8.41	132.43	986.90
1	131.05	3.60	3.91	18.42	144.20	3.46	3.91	17.70	137.47	3.33	3.93	8.48	134.05	3.25	3.83	8.49	133.69	987.45
1	125.92	3.51	3.90	18.00	140.90	3.35	3.89	17.22	133.73	3.38	3.98	8.49	134.21	3.19	3.84	8.31	130.85	978.14
6	124.64	3.48	3.89	17.89	140.04	3.37	3.89	17.33	134.59	3.53	3.98	8.87	140.22	3.35	3.86	8.68	136.68	991.02
2	126.17	3.52	3.89	18.10	141.69	3.47	3.89	17.84	138.55	3.43	3.96	8.66	136.89	3.25	3.85	8.44	132.90	995.00
9	127.97	3.45	3.90	17.68	138.40	3.43	3.89	17.63	136.92	3.47	3.94	8.81	139.27	3.22	3.89	8.38	131.95	983.79
1	128.48	3.45	3.88	17.78	139.18	3.48	3.88	17.94	139.33									995.54
5	126.95	3.26	3.92	16.63	130.18					3.61	3.91	9.24	146.06	3.38	3.82	8.85	139.35	999.87
6	127.20	3.29	3.93	16.74	131.09	3.30	3.90	16.92	131.41	3.63	3.93	9.24	146.06	3.33	3.83	8.70	136.99	986.79
9	125.41	3.34	3.93	16.99	133.80	3.42	3.90	17.54	136.22	3.57	3.94	9.06	143.22	3.34	3.82	8.75	137.78	982.15
5	126.95	3.52	3.93	17.91	140.20					3.49	3.92	8.90	140.69	3.30	3.82	8.65	136.21	989.08
5	126.95	3.46	3.95	17.52	137.15	3.46	3.90	17.74	137.77	3.68	3.92	9.39	148.44	3.43	3.82	8.98	141.40	1003.80
0	123.10	3.37	3.95	17.06	133.55	3.37	3.89	17.32	134.52	3.59	3.94	9.11	144.01	3.37	3.83	8.80	138.57	978.66
4	126.69	3.42	3.93	17.40	136.21	3.43	3.91	17.54	136.22	3.57	3.93	9.09	143.69	3.40	3.83	8.88	139.83	996.81
	2384.03				276299				233178				2642.30				2585.23	19763.62
	125.47				138.12				137.16				139.07				136.06	988.18
	125.67				138.34				137.37				139.29				136.27	989.7

D HORSE POWER—STEAM ENDS

2.8153		N° 3 - Spring - 40 Lb. Head End - K = 2.81225				Crank End - K = 2.8028				N° 4 - Spring - 16 Lb. Head End - K = 7.25597				Crank End - K = 7.24644				
P	I.H.P.	Area	Length	M.E.P.	I.H.P.	Area	Length	M.E.P.	I.H.P.	Area	Length	M.E.P.	I.H.P.	Area	Length	M.E.P.	I.H.P.	Totals
0	107.26	3.83	3.90	39.3	110.51	3.80	3.86	39.4	110.43	3.52	3.91	14.40	104.49	3.54	3.89	14.56	105.51	864.06
25	110.50	3.95	3.89	40.6	114.18	3.89	3.86	40.3	112.95	3.72	3.97	14.98	108.70	3.64	3.91	14.89	107.90	887.19
80	112.03	3.94	3.89	40.5	113.9	3.95	3.86	40.95	114.78	3.60	4.01	14.36	104.20	3.57	3.93	14.53	105.29	879.28
3	110.43	3.96	3.89	40.75	114.6	3.95	3.86	40.95	114.78	3.60	3.96	14.55	105.57	3.60	3.94	14.62	105.94	882.29
2	111.54	3.91	3.91	40.00	112.99	3.93	3.87	40.6	113.79					3.71	3.92	15.14	109.71	886.94
7	111.96									3.70	3.96	14.94	108.40	3.67	3.92	14.98	108.56	888.42
65	111.62	3.91	3.90	40.1	112.77	3.86	3.88	40.8	114.36	3.56	3.92	14.54	105.50	3.67	3.92	14.98	108.56	885.33
34	110.76	3.88	3.90	39.8	111.93	3.86	3.87	40.9	114.64	3.58	3.94	14.43	104.71	3.61	3.92	14.73	106.74	878.19
		3.94	3.94	40.0	113.49	3.90	3.86	40.42	113.29	3.61	3.97	14.55	105.57	3.62	3.92	14.77	107.03	877.35
15	113.03	3.96	3.90	40.6	114.18	3.94	3.86	40.82	114.41					3.61	3.92	14.73	106.74	885.99
25	107.69	3.85	3.89	39.6	111.36	3.81	3.87	39.38	110.37	3.68	3.96	14.87	107.89	3.69	3.91	15.11	109.49	879.11
		3.94	3.90	40.4	113.62	3.96	3.87	40.93	114.72	3.62	3.99	14.52	105.36	3.60	3.92	14.69	106.45	879.04
0	109.80	3.88	3.90	39.82	111.98	3.82	3.88	39.40	110.43	3.64	3.94	14.78	107.24					879.05
9	109.51	3.86	3.90	39.6	111.36	3.78	3.86	39.18	109.81	3.65	3.93	14.86	107.83	3.68	3.91	15.06	109.13	881.62
55	111.34	3.92	3.89	40.32	113.39	3.92	3.86	40.62	113.85	3.66	3.94	14.87	107.89	3.68	3.91	15.06	109.13	881.25
8	112.05	3.96	3.89	40.73	114.54	3.93	3.86	40.71	114.10	3.64	3.97	14.67	106.45	3.65	3.93	14.86	107.68	883.89
45	111.06	3.93	3.89	40.4	113.62	3.94	3.85	40.95	114.78	3.65	3.95	14.78	107.24	3.70	3.91	15.14	109.71	884.64
93	109.60	3.85	3.89	39.6	111.36	3.84	3.88	39.68	110.99	3.73	3.97	15.03	109.06	3.74	3.92	15.27	110.65	886.58
50	111.21	3.88	3.88	40.0	112.49	3.87	3.86	40.12	112.45					3.64	3.92	14.86	107.68	876.17
28	110.59	3.90	3.91	39.9	112.21	3.89	3.86	40.32	113.01	3.61	3.95	14.62	106.08	3.66	3.92	14.94	108.27	878.20
	1992.01				2142.99				2147.94				1812.18				2050.17	17630.60
	110.67				112.79				113.05				106.60				107.90	881.53
	110.84				112.97				113.23				106.77				108.07	883.20

ATED HORSE POWER—AIR ENDS

Injection to Intercooler - South Pump 5½ Dia x 11½ Stroke Scale 100 57 R.P.M.						Injection To Intercooler - North Pump 5½ Dia x 11½ Stroke - Scale 100 - 57 R.P.M.						Circulating Pump 10½ Dia x 19⅛ Stroke - Scale 30 57 R.P.M.						Tank Pump - Scale - 30 5" Dia. x 13" Stroke - 57 R.P.M.						Air Pump - Scale - 10 20" Dia. x 12⅝" Stroke - 57 R.P.M.					
Time	Card No.	Card Area	Card Length	M.E.P.	I.H.P.	Time	Card No.	Card Area	Card Length	M.E.P.	I.H.P.	Time	Card No.	Area	Length	M.E.P.	I.H.P.	Time	Card No.	Area	Length	M.E.P.	I.H.P.	Time	Card No.	Area	Length	M.E.P.	I.H.P.
905	1					312	2	2.45	4.60	53.26	2.15	11.15	1	.39	3.52	3.32	.085	1000	1	1.21	3.82	950	.349	325	1	0.13	4.01	0.32	0.19
	2	2.40	4.55	52.75	2.13		3	2.51	4.60	54.57	2.20	11.16	2	.42	3.63	3.41	.87	1005	2	1.59	3.87	1232	.453		2	.44	4.00	1.10	.65
	3	2.44	4.57	53.39	2.16		4	2.40	4.59	52.20	2.11	11.18	3	.36	3.52	3.07	.78	1015	3	1.60	3.90	1263	.464		3	.35	4.02	.87	.51
	4	2.46	4.56	52.69	2.12		5	2.41	4.60	52.39	2.12	11.17	4	.37	3.58	3.14	.80	1018	4	1.09	3.79	863	.317		4	.27	4.01	.67	.40
	5	2.37	4.57	51.86	2.10		6	2.41	4.61	52.28	2.11	11.19	5	.40	3.50	3.45	.98	1022	6	1.09	3.84	852	.313		5	.36	4.02	.89	.53
	6	2.37	4.55	52.09	2.10		7	2.44	4.62	52.81	2.13	11.21	6	.26	3.46	2.25	.58		7	1.30	3.79	1029	.378	335	6	.41	4.00	1.03	.60
							8	2.60	4.62	56.28	2.27	11.22	7	.27	3.47	2.33	.59	1033	8	1.35	3.82	1060	.389						
						345	9	2.51	4.60	54.57	2.20	11.23	8	.25	3.48	2.15	.55												
			Averages		2.12						2.16						.74						.38						.48

FIG. 3

No 1 Pump - Scale - 30 6" Dia x 7⅛" Stroke - 57 R.P.M.						No 2 Pump - Scale 30 6 Dia x 7⅛" Stroke - 57 R.P.M.						No 3 Pump - Scale 100 - 6" Dia. x 7⅛" Stroke - 57 R.P.M.						No 4 Pump - Scale 150 6" Dia x 7⅛" Stroke - 57 R.P.M.						Total I.H.P		
Time	Card No.	Area	Length	M.E.P.	I.H.P.	Time	Card No.	Area	Length	M.E.P.	I.H.P.	Time	Card No.	Area	Length	M.E.P.	I.H.P.	Time	Card No.	Area	Length	M.E.P.	I.H.P.			
1:40	1	.71	4.00	5.31	0.16	10.05	1	1.67	3.75	13.36	0.90	11.06	1	1.45	3.71	39.08	1.16	12.50	1	2.57	3.78	102.0	3.04	Intercooler Pump	2.12	
	2	.85	4.00	6.38	.19		2	2.07	3.74	16.61	.99		2	1.74	3.71	46.98	1.39		2	2.63	3.75	103.2	3.13	" "	2.16	
	3	.74	4.00	5.55	.17		3	1.68	3.74	13.48	.40		3	1.95	3.72	52.42	1.56		3	2.51	3.78	99.6	2.96	Circulating "	.74	
	4	.84	4.00	6.30	.18		4	1.78	3.74	14.28	.43		4	1.93	3.73	51.74	1.54		4	2.60	3.65	106.8	3.18	Tank "	.38	
	5	.58	4.00	4.35	.13		5	1.85	3.74	14.84	.44		5	1.70	3.70	45.95	1.37		5	2.60	3.66	106.6	3.17	Air "	.48	
1:51	6	.93	4.00	6.96	.21	10.14	6	1.98	3.78	15.71	.47	11.15	6	2.07	3.71	55.79	1.66	1:10	6	2.46	3.67	101.3	3.02	No 1 Feed Water "	.17	
					.17						.49						1.45						3.08	No 2 " " "	.44	
																								No 3 " " "	1.45	
																								No 4 " " "	3.08	
																								Total "	11.02	HP

FIG. 4 I. H. P. OF AUXILIARIES

Time	Revolutions	Gauge Board Pressures: Steam	Condenser	Intercooler	Air	Receivers 1	2	3	Main Calorimeter: Temper.	Ins. Press	Scratched	Moisture	Barometer	Outside Tem.	Nº1 Air Ent. Temp.	Nº1 Air Jack. Outlet Temp.	Time For 100 Revs.	Slow Watch	Temperatures: Nº2 Air Inlet	Nº2 Air Jacket Outlet	Nº2 Steam Inlet	Nº3 Air Jacket Outlet	Nº2 Air Discharge	Nº3 Air Discharge	Nº1 Steam Exhaust	Nº2 Steam Exhaust	Nº3 Steam Exhaust	Pressures in Receivers 1	2	3
	1	2	3	4	5	6	7	8	9	10			11	12	13	14			15	16	17	18	19	20	21	22	23	24	25	26
7 00 AM	847805	238	265	195	70	120	32	-18		17			2849	-1.0	80.6	54	1:40.8		112	66.5	355.0	72.0	986	985	3480	2793	2072	228	93	73
7 15	848126	244	270	200	70	122	33	-17	243	17	284	53	2849	-1.0	81.6	54	1:50.3		113	68.0	354.0	74	1026	1025	3499	2801	2093	230	112	80
7 30	848743	246	27	200	71	119	303	-16	244	16	310	51	2848	-08	83.2	57	1:47.6		114	68.0	353.0	75	1032	1048	3483	2805	2092	214	112	83
7 45	849440	242	27	205	72	121	31	-13	246	16	0.0	69	2847	+1.0	83.8	58	1:42.8		113	70.5	351.6	78.5	1050	1060	350.	2808	2095	210	108	78
8.00	850122	245	27	206	72	120	31	-1.8	222	16	74	68	2847	0.0	84.0	58	1:44.4		112	72.0	351.6	80.5	1068	1076	3493	2808	2098	210	104	74
8.15	851626	240	265	206	72	120	31	-1.3	244	15	294	52	2847	-0.5	83.6	58	1:46		113	73.0	352.6	82.5	1073	1086	3506	2810	2096	213	103	78
8.30	853018	245	265	206	72	120	314	-13	233	15	174	59	2847	-0.6	83.8	58	1:48.4		114	72.0	350.5	83.	1063	1075	3493	2810	2085	210	108	77
8.45	853804	243	265	208	72	120	31	-13	214	15	0.0	69	2847	+0.4	83.8	59	1:46.6		118	73.4	351.8	83.5	1073	1079	350	2822	2096	210	104	76
9.00	854151	248	265	203	72	120	31.5	-1.6	236	14	236	56	2847	0.0	84.2	59	1:44.2		110	73.6	352.	83.6	107.	1084	3503	2830	2092	211	104	76
9.15	855004	244	27	208	71	121	32	-11	233	15	184	59	2846	-0.8	83.9	59.4	1:46.8		116	74.6	352.	83.1	1063	1078	351	2812	2096	210	105	79
9.30	855834	242	265	210	72	119	31	-11	234	15	196	58	2847	-0.8	83.6	59.4	1:45.6		118	74.0	353.	83.8	1066	107	352	2790	2075	211	104	78
9.45	856657	240	264	205	72	121	30	-11	245	15	254	52	2845	0.0	85.2	59.4	1:47.4		120	74.0	353.1	84.0	1068	1078	3493	2793	2080	208	104	73
10.00	857464	243	265	205	72	120	31	-1.8	246	15	294	52	2850	-0.8	84.8	59.8	1:47.6		110	73.8	354.5	83.8	1068	1078	354	2804	2072	211	108	74
10 15	858279	244	265	205	72	123	31	-1.5	241	15	274	53	2851	-0.8	84.9	59.2	1 52		120	74.5	353.2	84.0	1070	1078	350	2803	2083	210	110	80
10.30	859194	238	265	197	71	120	31	-1.6	235	15	204	57	2852	-0.4	84.0	59.2	1:53		122	74.2	353.0	84.1	107.	1084	3498	2806	2088	208	108	80
10:45	860031	240	265	208	71	120	30	-1.0	237	16	224	63	2850	-0.6	84.2	59.0	1:45.8		120	73.6	352.0	84.0	1074	1090	3502	2806	2082	211	108	78
11:00	860887	240	265	20	72	122	31	-2.0	244	16	294	52	2851	-1.0	84.0	59.0	1:46		120	74.5	3500	84.2	1075	109	352.0	2796	2066	218	107	76
11:15	861749	245	265	20	72	121	31	-1.0	238	15	234	56	2851	-1.0	84.0	58.8	1:45.6		115	73.4	350.2	84.0	1080	1094	3503	2805	2111	210	105	76
11:30	862605	240	265	20	72	122	31	-1.0	235	15	204	57	2851	-1.0	84.2	58.4	1:45		120	74.5	352.	84.0	1083	1094	3503	2810	2084	209	105	76
11:45	863504	245	265	205	72	121	31	-1.1	241	15	274	54	2852	-0.5	85.2	58.0	1:40		120	74.0	351.2	83.5	1079	1114	3524	2804	2111	209	104	73
12:00	864338	240	265	206	72	121	31.5	-1.0	244	15	414	45	2850	+0.4	85.2	58.0	1:40		120	73.0	351.6	83.5	1068	1083	3510	2810	2114	208	103	76
12:15	865209	245	265	208	68.5	120	31	-1.1	238	15	204	58	2850	0.0	85.6	57.6	1:38.2		120	73.0	349.2	83.2	1068	1083	3510	2806	2116	210	100	68
12:30	866139	240	265	200	72	121	31.5	-1.2	240	15	284	52	2850	-1.0	84.4	58.0	1:43.4		120	73.1	350.0	83.4	1082	1094	353	2806	2103	210	101	70
12:45	866991	246	265	202	72	122	31.5	-1.0	235	15	204	58	2850	-0.8	84.4	58.0	1:45.8		120	74.2	353.1	84.0	1080	1091	3528	2806	2108	200	103	70
1 00	867813	245	265	200	70	121	31.4	-1.0	214	15	0.00	69.6	2850	0.0	84.6	58.2	1:45.8		120	73.2	353.0	83.6	1070	1082	351.	2806	2098	212	103	68
1 15	868732	245	265	20	71	121	31	-1.0	246	15	304	51	2852	-0.6	84.0	58.4	1:44.4		114	73.5	352.2	84.0	1080	1092	352	2800	2102	210	100	70
1 30	869581	242	26.5	205	71	121	30	-1.0	214	14	0.00	69.4	2852	-1.0	85.0	58.0	1:47		120	73.5	351.0	84.0	1086	1092	3505	2798	2105	206	100	70
1.45	870436	243	265	21	69	119	29	-0.8	238	15	224	56	2850	-1.0	85.3	59.2	1:50.4		122	74.6	351.0	85.0	1080	1085	349.	2797	2115	208	103	72
2.00	871280	242	265	21	71	118	29	-1.0	235	15	244	55	2850	-1.2	85.0	59.0	1:48.8		126	76.0	350.0	85.0	1078	1084	349.	2798	2116	204	102	70
2.15	872161	242	265	208	72	121	30	-1.0	235	15	94	64	2850	-1.0	84.4	59.0	1:45.8		114	74.6	351.0	85.0	1080	1092	351.	2796	2106	206	103	72
2.30	873016	245	265	206	72	121	30	-1.0	234	15	194	58	2849	-1.0	84.8	58.5	1:45		120	74.6	351.0	85.0	1080	1088	3505	2782	2110	208	102	72
2.45	873871	245	265	206	72	121	31	-1.0	214	15	0.00	69	2850	-1.0	85.0	57.8	1:41.8		120	74.5	351.5	84.6	1084	1094	351.5	2800	2106	206	103	73
3.00	874717	240	265	206	72	121	31	-1.0	213	15	0.00	69	2852	-1.0	84.6	58.4	1:47		120	74.6	351.5	84.0	1085	1096	3528	2810	2105	204	102	72
3.15	875587	242	265	20	72	120	31	-0.8	250	15	354	48	2852	-0.8	84.6	58.6	1:49.8		123	73.4	349.0	83.2	1083	1094	350.	2803	2112	208	104	70
3.30	876458	245	265	20	72	118	31	-0.9	247	15	324	50	2850	-1.0	84.4	58.0	1:45		120	73.0	349	83.0	1084	1102	349.	2812	2111	209	107	72
3.45	877267	243	265	20	72	121	31	-0.5	240	15	244	54	2851	-1.0	84.4	58.0	1:44.4		120	73.0	351	83.0	1086	1094	351.	2810	2110	200	104	73
4.00	878121	242	265	205	72	121	31	-1.0	243	15	284	53	2851	-1.0	84.2	58.0	1:47		120	73.0	350.5	83.	1086	1100	350	2803	2108	205	104	74
4.15	878976	245	265	203	71	120	31	-1.0	215	15	0.00	69.4	2851	0.0	84.2	58.0	1:43.2		122	73.0	350	83.7	1086	1092	3498	2806	2106	208	102	74
4.30	879806	245	265	203	71	120	30	-1.0	247	15	264	54	2851	-1.2	84.4	58.0	1:49.4		123	73.6	349.5	83.6	1078	1092	3508	2806	2106	208	102	72
4.45	880727	243	265	202	72	120	31	-1.0	238	15	174	59	2851	-1.3	84.4	58.0	1:45		122	73.2	350	83.5	1086	1100	3515	2810	2108	205	101	70
5.00	881672	240	265	204	70	120	31	-1.2	250	15	334	48	2851	-1.2	83.8	58.0	1:55		120	73.0	351	83.6	1078	1092	3503	2806	2108	206	102	70
Average	54965	243.8	264.9	203	71.42	120.7	30.94	-1.24	234.7	15.4		57.4	2850	-0.63	84.3	58.34	1:45.76		117.6	73.07	351.2	83.8	1076	1088	3504	2805	2094	2089	104.1	73.6
	R.P.M.	Lbs.	Inches	Lbs.	Lbs.	Lbs.	Lbs.	Inches	F°	Lbs.	F°	%	Inches	C°	C°	F°	Min & Sec.		C°	F°	F°	F°	C°	C°	F°	F°	F°	Lbs.	Lbs.	Lbs.
C° Reduced To F°														30.9	183.7				53.3				240.9	234.7					

TABLE 5 LOG OF TEST, MARCH 8, 1906

REHEATERS

7 The high pressure cylinder is jacketed with steam coming from the drip of the main separator. This is led in turn through a reducing valve to the first reheater and a second reducing valve to the second and third reheaters, and then is delivered through a float trap to one of the series of feed water heaters.

FEED WATER HEATING SYSTEM

8 The feed heating system connected with the engine is divided into five approximately uniform steps with the object of gradually adding heat to the feed water by steam of progressively higher temperature which has done some work.

9 Condensation from the condenser, removed by the air pump, is raised to an open oil skimming tank by another pump.

10 An automatic float valve admits the feed to the preheater, where it gains in weight and temperature by contact with the exhaust from the low pressure cylinder. The feed is raised by a pump to an elevated heater where it meets steam drawn during expansion through a special valve from the low pressure cylinder. By gravity the feed falls to a heater receiving the discharge from the low pressure jacket line which came from the third receiver. A second pump transfers the feed to a heater receiving the second intermediate jacket water and the discharge from the trap on the reheater line.

11 Pumped again to the last heater, the feed meets steam drawn through the first intermediate jacket from the first receiver. A fourth pump drawing from the last heater returns the feed, augmented in pressure, weight and temperature through an economizer to the boilers.

AUXILIARIES

12 The several auxiliary pumps are driven by oscillating levers actuated by a crank connection with the main engine shaft. These auxiliaries consist of an air pump for removing condensation from the surface condenser, a tank pump for elevating the condensation to the oil skimming tank, a pump for circulating water through the condenser, a double pump supplying water to the air cylinder jackets and spray intercooler, an oil pump for removing oil from the oil separator placed in the low pressure engine exhaust, four pumps transferring feed water from heater to heater and to the boiler, and a small air pump to charge air chambers on pump lines.

AIR CYLINDERS

13 Interposed between each steam cylinder and the guides is an air compressing cylinder. The first stage compression cylinders are attached to high and low pressure engines and the second stage cylinders are attached to the intermediate engines. All air cylinders have Corliss valves operated from eccentrics, the cylinders and heads are

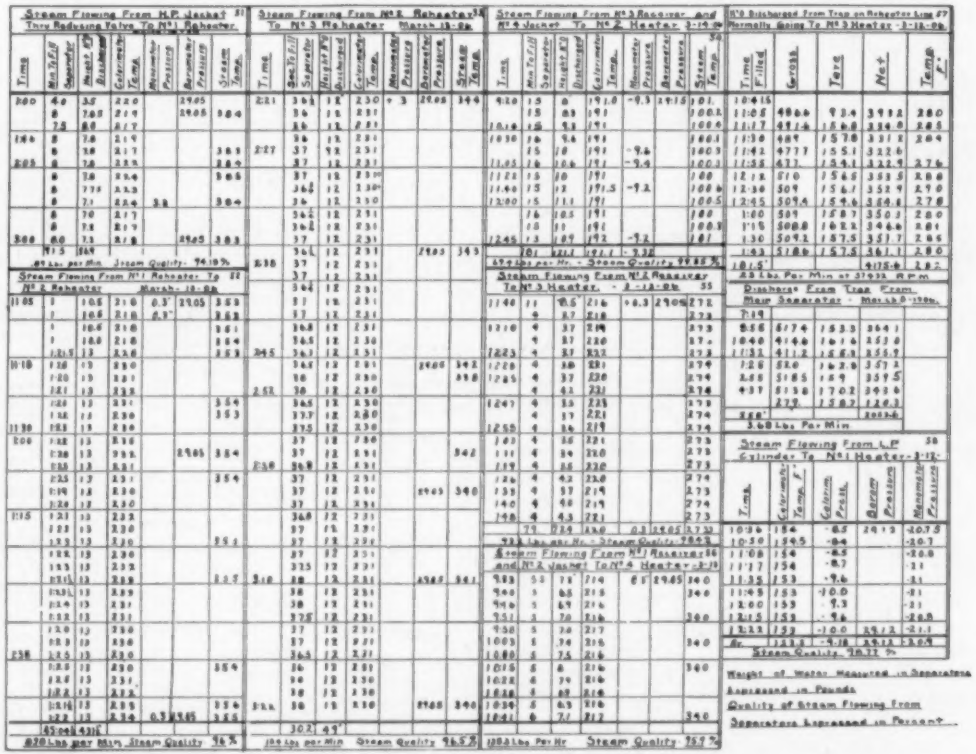
Time	Revolutions	Gauge Board Pressures: Steam	Condens.	Intermediate	Air	Receivers 1	2	3	Steam Temp in Calorimeter	Barometer	Outside Temp	Time For 100 Revs	Stage Ratios	Temperatures: N°4 Steam Inlet	N°3 Steam Exhaust	N°4 Steam Exhaust	N°3 Steam Exhaust	Pressure in Reservoirs
	1	2	3	4	5	6	7	8	9	11	12			17	21	22	23	24
AM 6.46	2.87458	240	27.0	21	71	120	30	-1.0	274	29.79	-11.0	1'41"		350.0	349.0	279.5	217.0	209
7:00	2.88376	240	27	21	72	120	30	-0.0	273	29.74	-11	1'41		352	350	279.0	219.5	209
7:15	2.89787	240	26.8	21	72	121	31	-0.7	276	29.80	-11	1'46		352	350	280	219	209
7:30	2.89980	240	26.8	21.5	72	119	31	-0.7	275	29.80	-11	1'43.5		350	349.5	280.5	219	209
7:45	2.90089	242	27	21.5	72	119	31	-0.8	276	29.82	-11	1'42.0		352	351	280	219	209
8:00	2.91707	240	27	21.5	72	120	30	0.0	274	29.84	-10.5	1'46.0		349	349	279	217	209
8:15	2.88826	243	27	21.5	72	119	30	-1.1	273	29.84	-10	1'41.8		349	349	281	219	209
8:30	2.89791	245	27	21.7	71	120	30	-0.8	272	29.87	- 9.8	1'47		350	349	280	218	209
8:45	2.90226	243	27	21.5	68	120	30	-0.8	280	29.84	- 9.2	1'46		349	349	280.5	219	209
9:00	2.86114	243	26.9	21.5	70	120	30	-0.8	293	29.83	- 9.0	1'43		350	350	280	219.5	209
9:15	2.85970	246	26.9	21.5	70	120	30	-1.0	284	29.84	- 9.0	1'43.4		349	349	280	219	209
9:30	2.86931	244	27	21.4	72	120	30	-0.3	276	29.85	- 8.8	1'46		349	350	280.5	219	209
9:45	2.87486	245	27	21.3	72	121	31	-0.5	284	29.85	- 8.3	1'47		349	348	280	219	209
10:00	2.88230	244	27	21.3	72	120	31	-0.6	287	29.86	- 8.0	1'48.0		349	348.5	280	219	209
10:15	2.87367	243	27	21.4	71	119	30	-0.5	283	29.87	- 7.4	1'46.8		349.0	349	280.5	219	209
10:30	2.90230	241	27	21.5	71	120	30	-0.4	280	29.88	- 7.6	1'43.2		349	349	280.5	219	209
10:45	2.91089	242	27	21.5	72	120	30	-0.4	276	29.87	- 7.0	1'44.6		349	350	280	219	209
11:00	2.91947	244	27	21.4	72	119.5	30	-1.0	260	29.90	- 6.8	1'46.0		349	349	281	219.5	209
11:15	2.92798	244	27	21.3	71	119.5	30	-0.8	269	29.91	- 7.0	1'45.6		351.5	349.5	280	219	209
11:30	2.93652	246	27	21.5	70	119.5	30	-1.0	270	29.89	- 7.2	1'44.4		349	349	281	219	209
11:46	2.94578	240	27	21.6	71	120	30	-0.7	276	29.86	- 6.8	1'46.2						
	57.067	244.14	26.97	21.36	71.39	119.81	30.24	-.705	28.685	29.84	-8.72	105.346'		349.96	349.5	280.1	219.2	209.7
	RPM	Lbs.	Inches	Lbs.	Lbs.	Lbs.	Lbs.	Inches	F°	Inches	C°	Min & Secs.		F°	F°	F°	F°	Lbs.
											16.0°							

TABLE 6 LOG OF TEST OF MARCH 17

Time	Pressure in Reservoirs: 2	3	Temperatures: N°3 Steam Inlet	N°4 Steam Inlet	N°4 Steam Exhaust	N°3 Steam Exhaust	Pressure in Heater: N°1	N°2	N°3	N°4	Temperatures: First Water From Condenser	Condenser Circulating Water: To	From	At Pumps: N°1	N°2	N°3	N°4	Condenser Vacuum
	25	26	27	28	32	35	36	37	38	39	40	41	42	43	44	45	46	49
AM 6.46	112	110	298.0	101.6	112.0	67.5	-11.0	0.0	2.6	1.89	—	—	—	44	102.5	267.0	31.4	26.9
7:00	111	110	299.3	101.2	113	69	- 8	0	31	1.15	83.0	41.0	87.5	43	106	268	31.2	26.5
7:15	107	106	299.2	100.4	112	68	- 8.5	0	32	1.20	85.5	41	87.	45	106	268.5	30.4	26.7
7:30	101	106	298	101	110.5	67.5	- 8.7	0	32	1.20	86	40.5	87.5	44	106	266	29.5	26.6
7:45	108	106	298	101.3	117	68	- 8.5	0	32	1.25	86	40.5	87.5	44	106	267	29.7	26.6
8:00	105	103	300	99.8	117.5	66	- 8	0	28	1.00	86.5	41	88.0	44	105	270	32.5	26.8
8:15	105	104	296	101.2	112	69	-11	0	29	1.00	87.5	41	88.5	45	101	272	33.7	26.6
8:30	106	101	296.4	100	111	67	-13.5	0	28	1.02	87	41	87.5	45	101	265	32.5	26.6
8:45	105	101	297.2	100.6	111.5	69	-10	0	34	1.15	87.5	41	87.5	44.5	104	273	33.7	26.5
9:00	105	100	299.5	100.6	114	69	- 7	0	32	1.18	87.4	41	88.5	45	105	270	32.3	26.5
9:15	105	100	299	101.2	111.5	69	-10.5	0	31	1.05	88.5	41	88.5	44.5	105	268	32.9	26.5
9:30	100	100	297.2	100.3	112	69	-10.5	0	31	1.00	88.5	41	88.5	44	103	265	32.6	26.6
9:45	102	98	296	100	110	68	- 9	0	30	1.10	88	41	88	44	104	268	32.8	26.6
10:00	100	98	298.4	101.2	111	65	- 9.5	0	32	1.10	88	41.5	87	44	106	268	33.2	26.6
10:15	100	96	299	101.3	111	66	- 9.2	0	33	1.10	87	41.5	88	44	106	270	33.1	26.6
10:30	100	96	298	101.2	111	64.5	-10.5	0	30	1.03	87.5	41.5	87	44	106	270	33.0	26.7
10:45	100	96	297	100.2	110	67.5	- 9.5	0	30	1.10	87.5	41.5	87	44	105	266.5	32.7	26.7
11:00	105	98	297	101.4	111	66	- 9.7	0	32	1.10	87.5	41.5	87.5	44	106	273	33.9	26.6
11:15	105	98	296	100	110.5	68	- 9.2	0	30	1.04	88	41.5	87	44	106	273	33.9	26.6
11:30	105	98	298	100.6	110.5	68	- 10	0	30	1.05	87	41.5	87	44	105	271	33.8	26.6
11:46	104.55	95.6	297.7	100.74	111.8	67.7	-9.48	0	30.8	1.104	87.0	41.3	87.7	44.4	104.8	268.6	32.14	26.7
	Lbs	Lbs	F°	C°	F°	C°	Inches	Inches	Lbs	Lbs	F°	F°	F°	C°	F°	F°	F°	Inches
C° Reduced To F°				218.3		152.9								112.				

TABLE 7 LOG OF TEST OF MARCH 17

water jacketed, and between the two stages air is cooled in a spray intercooler. Air is admitted to the first stage cylinders through short lengths of pipe from without the building and is discharged to a receiver before entering the distributing system.



Steam Flowing From H.P. Jacket & Thru Reducing Valve To N°1 Reheater.

Time	Min To Fill Separator	Height Ft Discharged	Calorimeter Temp.	Manometer Pressure	Barometer Pressure	Steam Temp.
7:00	4.0	3.5	220		29.05	
	8	7.05	219		29.05	284
	7.5	8.0	217			
1:00	8	7.0	219			
	8	7.0	217			283
2:05	8	7.0	225			284
	8	7.0	224			285
	8	7.15	223			
	8	7.1	224	5.8		284
	8	7.0	217			
	8	7.2	217			
3:00	8.0	7.3	218		29.05	283
	71.5	64.9				

69 Lbs per Min Steam Quality 74.19%

Steam Flowing From N°1 Reheater To N°2 Reheater March 13-08

Time						
11:05	1	10.5	216	0.3"	29.05	283
	1	10.6	216	0.3"		283
	1	10.6	216			281
	1	10.6	216			284
	12.5	13	226			283
11:10	7.15	13	230			
	7.20	13	231			
	7.21	13	233			
	7.22	13	231			284
	7.45	13	230			283
11:30	7.53	13	230			
2:00	7.52	13	230			
	7.38	13	231		29.05	284
	7.55	13	231			
	7.35	13	231			284
	7.19	13	230			
	7.20	13	230			
1:15	7.21	13	229			
	7.22	13	230			
	7.23	13	230			284
	7.23	13	230			
	7.23	13	232			
	7.21	13	229			284
	7.20	13	229			
	7.24	13	231			
	7.24	13	230			
	7.22	13	230			
2:38	7.25	13	230			
	7.26	13	231			284
	7.28	13	232			
	7.29	13	235			284
	7.27	13	234	0.3	29.05	285
	65.04	43.15				

670 Lbs per Hour Steam Quality 96%

Steam Flowing From N°2 Reheater To N°3 Reheater March 13-08

Time	Sec To Fill Separator	Height Ft Discharged	Calorimeter Temp.	Manometer Pressure	Barometer Pressure	Steam Temp.
2:21	3.63	1.2	230	+ 3	29.05	349
	3.6	1.2	231			
	3.6	1.2	231			
2:27	3.7	1.2	231			
	3.7	1.2	231			
	3.7	1.2	230			
	3.65	1.2	230			
	3.6	1.2	230			
	3.62	1.2	231			
	3.62	1.2	231			
	3.7	1.2	231			
2:38	3.7	1.2	231		29.05	343
	3.64	1.2	231			
	3.7	1.2	231			
	3.64	1.2	231			
	3.7	1.2	231			
	3.68	1.2	231			
	3.65	1.2	230			
2:43	3.63	1.2	231		29.05	342
	3.6	1.2	230			340
	3.7	1.2	230			
	3.7	1.2	230			
2:53	3.6	1.2	230			
	3.65	1.2	230			
	3.67	1.2	230			
	3.75	1.2	230			
3:00	3.7	1.2	230			
	3.7	1.2	231			342
3:08	3.68	1.2	231			
	3.7	1.2	230		29.05	340
	3.7	1.2	231			
3:15	3.68	1.2	231			
	3.7	1.2	231			
	3.7	1.2	229			
	3.7	1.2	230			
	3.75	1.2	231			
3:18	3.8	1.2	231		29.05	340
	3.8	1.2	231			
	3.8	1.2	231			
	3.75	1.2	231			
	3.7	1.2	230			
	3.8	1.2	230			
3:28	3.75	1.2	231			
	3.8	1.2	230			
	3.8	1.2	230			
	3.8	1.2	230			
3:34	3.6	1.2	230		29.05	340

302 Lbs per Min Steam Quality 96.5%

Steam Flowing From N°3 Receiver and N°4 Jacket To N°2 Heater 2:19 PM

Time	Min To Fill Separator	Height Ft Discharged	Calorimeter Temp.	Manometer Pressure	Barometer Pressure	Steam Temp.
9:20	1.5	0	191.0	-9.3	29.15	281
	1.5	0.3	191			1000
10:16	1.6	9.3	191			1000
10:30	1.6	9.6	191			1000
	1.5	10	191	-9.6		1000
11:05	1.6	10.6	191	-9.9		1000
11:25	1.5	10	191			1000
11:40	1.5	11	191.5	-9.2		1000
12:00	1.5	11.1	191			1000
	1.6	10.5	191			1000
	1.5	11	191			1000
12:45	1.3	10.9	192	-9.2		1001
	70	1211	191.1	9.32		

694 Lbs per Hr. - Steam Quality 99.88%

Steam Flowing From N°2 Reheater To N°3 Heater. - 3:12-08

Time						
11:40	11	10.5	216	+0.3	29.05	272
	9	8.7	218			272
12:10	9	8.7	218			272
	9	8.7	220			272
12:25	9	8.7	222			272
12:26	9	8.8	221			274
12:35	9	8.7	220			274
12:37	9	8.7	220			274
12:47	9	8.8	225			274
	9	8.7	221			274
12:55	9	8.6	219			274
1:03	9	8.6	221			273
1:11	9	8.6	220			273
1:19	9	8.6	220			273
1:26	9	8.2	220			274
1:33	9	8.7	219			273
1:40	9	8.8	219			274
1:48	9	8.3	221			273
	79	72.4	220	0.3	29.05	1730

933 Lbs per Hr. - Steam Quality 78.6%

Steam Flowing From N°1 Receiver and N°2 Jacket To N°4 Heater 2:10

Time						
9:33	5.3	7.8	214	6.1	29.05	340
9:40	5	6.5	215			340
9:40	5	6.9	214			
9:51	5	7.0	216			340
9:58	5	7.0	217			
10:03	5	7.0	216			340
10:80	5	7.5	216			
10:15	5	8	216			340
10:22	6	7.9	216			
10:28	5	6.8	216			
10:36	5	6.3	216			
10:41	6	7.1	212			340

1208 Lbs Per Hr Steam Quality 75.7%

N°3 Discharged From Trap on Reheater Line #7 Normally Going To N°3 Heater - 3:12-08

Time Filled	Grams	Tare	Net	Temp F°
10:45				
11:05	4906	934	3972	280
11:17	4714	1548	3166	285
11:30	4889	1570	3319	284
11:42	4777	1551	3226	
11:58	4771	1549	3222	276
12:12	510	1546	3535	288
12:30	509	1541	3529	290
12:45	5094	1546	3548	278
1:00	509	1587	3503	280
1:15	5088	1622	3466	281
1:30	5092	1575	3517	286
1:43	5186	1575	3611	280
1:45			41786	282

231 Lbs Per Min at 31933 R.P.M.

Discharge From Trap From Main Separator - March 8-1908.

7:19				
9:56	6174	1533	3041	
10:40	4146	1616	2530	
11:32	4112	1561	2551	
1:26	5120	1629	3572	
2:25	5185	1629	3556	
4:37	5136	1702	3434	
	2.75	1587	1163	
288			20034	

348 Lbs Per Min

Steam Flowing From L.P Cylinder To N°1 Heater - 3:12-

Time	Calorimeter Temp F°	Calorim Press	Barom Pressure	Manometer Pressure
10:36	154	-8.5	29.13	-20.75
10:50	1945	-8.4		-20.7
11:08	154	-8.5		-20.8
11:17	154	-8.7		-21
11:35	153	-9.6		-21
11:45	153	-10.0		-21
12:00	153	-9.3		-21
12:15	153	-9.6		-20.8
12:33	153	-10.0	29.12	-21.1
Av.	153.8	-9.18	29.12	-20.94

Steam Quality 76.33 %

Weight of Water Measured in Separators Expressed in Pounds

Quality of Steam Flowing From Separators Expressed in Percent

TABLE 8 LOG OF QUALITY OF STEAM FLOWING TO STEAM RE-HEATERS AND FEED WATER HEATERS

TOTAL FEED WATER – MARCH 8 1906

TANK Nº 1				TANK Nº 2		
TIME WHEN FULL	WEIGHT FULL	WEIGHT EMPTY	NET WEIGHT	WEIGHT FULL	WEIGHT EMPTY	TIME WHEN FULL
				START		7.09AM
AM 7:15	32515	497.3	27542	3332.2	484.3	7:29.5
7:43.5	3233.4	497.8	2847.7			
			2755.6			
8:10	3226.4	496.6	2737.0	3326.2	489.2	7:56.5
			2730.0			
			2786.0	3258.6	473.6	8:25
8:40.5	3231.9	494.1	2737.8			
			2782.6	3264.0	481.4	8:54
9:08	3286.7	497.8	2788.9			
9:36	3260.7	490.3	2748.8			
			2762.5			
			2755.4	3237.4	483.6	9:50
10:03.5	3221.8	490.2	2731.6			
			2847.6	3327.2	479.6	10:18
10:33	3246.3	487.9	2746.4			
11:02	3286.0	487.2	2798.4	3234.6	539.2	10:46.5
			2898.8			
			2813.1	3291.2	478.1	11:16
11:30	3276.4	492.2	2784.2			
			2770.0	3248.5	473.5	11:44
11:57	3280.3	488.9	2791.4			
			2677.8	3229.2	551.4	12:10
12:22.5	3227.0	495.6	2731.4			
			2735.4	3236.8	701.4	12:35
12:50	3221.4	495.5	2725.9			
			2805.4	3236.7	661.3	1:03.5
1:17.5	3271.0	496.0	2775.0			
1:46.5	3272.9	495.4	2744.7	3232.2	477.5	1:31.5
			2817.5			
			2737.2	3232.7	495.5	2:00
2:14	3259.5	490.4	2769.1			
			2748.6	3229.2	476.1	2:28
2:42	3234.3	490.0	2729.3			
3:10.5	3237.9	489.6	2747.1	3234.9	487.3	2:56.5
			2748.3			
			2744.6	3232.4	478.0	3:25
3:38.5	3345.3	489.4	2855.9			
			2831.1	3321.0	489.9	3:54
4:08	3237.1	483.2	2743.9			
4:37	3349.0	478.5	2817.3	3236.3	619.0	4:23.5
			2870.5			
			2781.4	3231.1	471.7	4:50.5
5:20	3269.1	487.7	2781.4			
	11200.1	10965.6		6825.77	1075.34	
10 HOURS	TOTAL		17996.9 Lbs			

WATER FROM HEATER SYSTEM – MARCH 17-1906

TANK Nº 1				TANK Nº 2		
TIME FULL	GROSS	TARE	NET	GROSS	TARE	TIME FULL
				START		6:46AM
7:01.5	3226.6	478.8	2747.8			
			2813.6	3297.8	484.2	7:15.5
7:30	3255.0	424.9	2830.1			
8:04	3271.1	474.1	2798	3264.9	474.9	7:47
			2797			
			2789.0	3264.5	474.7	8:18
8:33.5	3231.3	485.2	2746.1			
			2806.1	3290.7	484.6	8:45.5
9:06	3281.2	489	2792.2			
9:31	3241.8	488.8	2777.9	3243.1	477.2	9:15.5
			2783			
			2784	3258.4	474.4	9:45.5
9:57	3233.3	484	2797.3			
			2791.1	3240.9	471.8	10:13
10:26	3277.1	491.2	2789.9			
10:55	3269.4	491	2776.8	3250.0	474	10:41
			2777.4			
			2750.2	3226.5	486.3	11:08
11:20.5	3233.5	490	2753.5			
			2779.7	3251	471.3	11:35
11:46	2878.0	480.2	2397.8			
	55596.1	5275.2	50320.9	32592.6	4761.9	
5 HOURS			50320.9			
Correction for water level			288			
Total			58250. lbs			

WATER FROM CONDENSER – MARCH 17-1906

TANK Nº 1				TANK Nº 2		
TIME EMPTY	GROSS	TARE	NET	GROSS	TARE	TIME EMPTY
				START		6:46
6:55	988.5	276.6	712.0			
			627.8	907.2	277.9	7:20
7:07	1000.4	122.6	877.8			
7:18	994.5	121.7	734.3	873.6	137.3	7:11
			812.8			
			734.6	871.2	136.6	7:33
7:31	1061.0	120.5	880.6			
			737.1	874.1	137.0	7:54
7:44	1005.2	122.5	882.7			
7:58	1007.3	120.6	789.3			
			886.7			
			844.9	984.2	139.3	7:50
8:11	1005.0	120.7	884.3			
			678.0	970	295	8:16
8:24	1004.5	119.1	885.4			
8:36	997.5	138.8	843.8	986.7	141.9	8:31
			858.7			
			845.4	983.3	136.3	8:49
8:51	997.8	126.6	871.2			
			641.2	979.5	138.3	8:56
9:05	1010.9	123.3	856.0			
			890.5	979.5	139	9:09
9:17	1005.2	120.6	884.6			
			841.1	979.5	138.1	9:33
9:30	999.0	120.3	878.7			
			837.2	976.7	139.5	9:36
9:46	1004	119.5	884.5			
9:54	1000	116.0	1011.7	1150.5	138.8	9:50
			690.0			
			837.3	978.7	139.6	10:00
10:06	1004	151.2	852.8			
			838.2	979.6	141.3	10:12
10:18	1002.5	138.0	864.5			
10:27	994.3	287.0	845.1	979.7	134.6	10:23
			687.3			
			842.1	980.7	138.6	10:33
10:39	1001.8	148.9	852.9			
			841.2	979.7	138.5	10:45
10:50	1010	126.7	733.3			
11:00	1002.7	123.1	698.1	993.1	295	10:55
			880.6			
			842.5	981.3	138.8	11:08
11:12	1046.6	121.6	925.0			
			679.4	981.8	302.4	11:16
11:21	1000.8	122.5	878.3			
11:34	1001.3	121.5	841.3			
			879.8			
			834.9	979.8	144.9	11:39
11:46	1030.0	122.2	915.8			
			492.3	832.6	340.3	11:46
	25096.0	3840.8		23889.9	4090.7	
5 HOURS	TOTAL		41256.4 Lbs			

TABLE 9 LOG OF FEED WATER BOTH TESTS

Time	Temperature									Pressure in Heater				Temperature			Air Pumps						Condenser Vacuum	Air leaving Intercooler
	No 3 Steam Inlet	No 4 Steam Inlet	No 3 Air Inlet	No 4 Air Discharge	No 3 Air Jacket Leaving	No 4 Air Discharge	No 4 Steam Exhaust	Preheater Feed	Intercooler Spray	Feed entering No 2 Heater	No 1	No 2	No 3	No 4	Cond Water from Condenser	Condenser Circulating Water To	Condenser Circulating Water From	No 1	No 2	No 3	No 4	Water From Intercooler	Air To Intercooler		
	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
700	284.0	103.5	12.0	25.5	83.0	11.3	89	7.0	85	-1.0	-2.2	30.5	107.5	81.5	6.0	29.5	11.3	20.1	24.8	33.5	15	82	24	47
715	290.8	102.2	11.2	27	83	11.4	88	7.0	85	-9	-1.8	31	107.5	81.5	6.0	30	11.4	20.5	27.0	33.5	15	82	24	47.5
730	293	103.2	11.1	28	84.9	11.42	85	7.0	84.5	-9	-1.9	31	108	85.5	6	31	11.5	20.4	27.0	33.5	15	85	25.9	47
745	291	102.0	11.5	32	87	11.42	85.5	7	82	-6	-3.2	30.5	107.5	88	6	32	11.5	20.3	27.0	33.1	15	85	25.9	47
800	291.2	102.0	12.0	33.6	87	11.42	85	7	78	-11	-3.0	31	108	88	6	31.5	11.6	20.2	27.0	33.2	15	84	25.9	47
815	293	102.2	12	35	85.6	11.6	87	7	78	-10.5	-3.0	31	108	88	6	31	11.58	20.2	27.05	33.4	15.5	86	25.9	48
830	292	102.3	11.5	34	85.8	11.63	89	7	80	-10	-3.0	31	108	88	6	31.5	11.55	20.25	27.0	33.3	14	87	25.9	47.5
845	292	102	11.6	36.3	86	11.56	91	7	81	-9.5	-2.8	31.5	110	88.5	6	31.5	11.5	20.3	27.2	33.6	14	86	25.9	47.5
900	292.2	101.6	11.6	36.0	86.3	11.55	92.5	7	75.5	-10.5	-3	32	109	89	6	31.5	11.5	20.05	27.1	33.5	14	87	25.9	47.5
915	292	101.2	12.0	36.8	87.8	11.6	93.5	7	74.5	-11.5	-4	31.5	109	89	6	31.5	11.5	20.1	27.1.5	33.5	13.5	88	25.9	47.5
930	292	101.2	11.2	36.4	88.1	11.6	94	7	74	-11.2	-4	30.5	101	89	6	31.5	11.45	20.0	26.9	33.45	14	88	25.9	47.5
945	292	101.6	11.0	36.5	87.4	11.55	94	7	74	-12.4	-4	31	108	88.5	6	31	11.45	20.0	26.9	33.5	13.5	87.5	25.9	47.5
1000	292	101.2	11	35	87.2	11.6	94	7	73.5	-11.5	-3	30	110	88.5	6	31	11.5	20.0	26.9	33.7	14	87	25.9	47
1015	292	100.0	11.2	37	87	11.45	94	7	73.5	-10.5	-3	31	110	88	6	30.1	11.45	20.15	27.0	33.6	13.5	87	25.9	47
1030	292	100.2	11.2	37	86.4	11.5	93.5	7	77	-10	-3.4	31	111	88	6	30.4	11.55	20.05	26.9	33.6	13.5	86	25.9	47
1045	292	100.0	12	37	86.6	11.6	93.5	7	74.5	-11.5	-3	31	109	88	6	31.0	11.4	19.9	26.9	33.6	14	87	25.9	47.5
1100	291	101.2	12	37.2	86.5	11.55	93.5	7	72	-10.3	-3	30	109	88.5	6	31.2	11.5	19.9	27.0	33.5	14	86	25.9	47.5
1115	292	102.6	11.6	37.3	86.2	11.45	93.5	7	74	-11	-3.5	31	108	88.5	6	31.1	11.4	20.06	27.0	33.6	13.5	87	26	47.2
1130	291.8	103	11	37	86.6	11.45	92.6	7	73.5	-10.6	-3.4	30.5	109	88.5	6	31.1	11.4	20.0	27.0	33.6	13.5	87	26	47.3
1145	291.2	102.2	11	37.2	87.4	11.6	92.6	7	74	-9.5	-3	31	107	88.5	6	32	11.45	20.1	27.1	33.6	13.5	86	26	47.6
1200	291.2	102	11	37	88	11.6	93.5	7	70	-10.5	-3	31	108	89.5	6	32.1	11.55	20.0	26.9.5	33.5	13.5	86	25.9	47.6
1215	290.5	101	11	36.8	88.0	11.65	94	7	70.1	-10.5	-3.3	30	107	90	6	33	11.5	20.0	26.9	33.1	13.5	87.5	25.9	47.6
1230	290.6	101	11	37	88	11.6	93.5	7	71.5	-12.0	-4.4	32	108	89	6	31.1	11.5	20.1	27.1	33.6	13.5	86	25.9	47.5
1245	291.2	101.5	11	37	86.0	11.5	93	7	73	-12.5	-3.6	32	110	89	6	31	11.4	20.0.6	27.1.5	33.8	13.5	86.5	26	47.8
100	291	101.2	11.2	37	88	11.65	93	7	70.5	-11.5	-4.7	32	110	89	6	31.1	11.4	20.1	27.0	33.65	14	86	26	47.5
115	291	101.2	11.5	37	87	11.68	93.5	7	73	-12	-3.2	31	109	89	6	31	11.35	20.2	26.9	33.6	14	87	26	47.5
130	290.6	101.2	12	37	87.6	11.65	93.5	7	73	-11	-3.4	31	109	88.6	6	31	11.4	20.16	26.7.5	33.6	14	87	26	47.5
145	291	101.0	12	38	88	11.6	93	7	80	-6	-0.7	31	107	88.6	6	31.2	11.35	20.5	26.8.5	33.5	13.5	87	26	47
200	290.6	100.2	12	38	87.6	11.3	93	7	73.5	-5	-2.1	31	107	88	6	31.3	11.3	20.35	26.86	33.5	14	87	26	47.5
215	291	102.5	11	38	87.3	11.4	93.5	7	65.5	-5	-5.7	30	108	89	6	31.4	11.35	20.0	26.85	33.6	14	87	26	47.5
230	290	102.6	11	37.8	87.0	11.38	93	7	61	-5.5	-5	31	107	89	6	32	11.3	19.8	26.76	33.6	13.5	87	26	47.6
245	291	103.0	11	37.5	87.2	11.4	91.5	7	57.5	-5.5	-4.1	31	108	89.5	6	32	11.35	19.6	26.9	33.6	14	87	26	47.5
300	291	103.6	12	37	87	11.4	91.5	7	55	-5.5	-4.1	32	108	89	6	31.4	11.3	19.4	26.9	33.7	14	87.6	26	48
315	291	103.4	12	36.6	87.2	11.62	91.5	7.5	87	-6	0.0	32.5	109	89	6	31.	11.3	20.5	27.1	33.7	13.5	87	26	48
330	291.2	103.0	12.3	36	87	11.4	93.5	7.5	87	-6	+5.0	32	107	89	6	31.2	11.3	20.65	27.0	33.6	13.5	87	26	48
345	292	103	12.0	36	87	11.4	93	7.5	87	-7.5	+3.0	32	108	89	6	31.2	11.3	20.8	27.0	33.6	13.5	87	26	48
400	291	103.6	12	36	87.6	11.35	93.5	7	87	-8	-0.8	32	110	89	6	31.2	11.3	20.7	27.0	33.2	14	86.5	26	48
415	291	103.2	12	36	86.5	11.4	93	7	87.5	-8	-1.1	32	109	89	6	31.4	11.4	20.7	27.0	33.0	14	87	26	48
430	291	103.2	12.2	37	86.8	11.38	93	7	87.5	-7.5	-1.2	31	109	89	6	31.4	11.3	20.6	27.0	33.0	14	86	26.9	48
445	291	102.6	12	36.2	87.0	11.58	94.5	7.5	86.5	-8.0	-1.4	31	110	89.5	6	33.	11.4	20.6	27.0	33.9	14	86	26.8	48
500	291	102.5	13.	35.0	87.	11.7	94	7.5	87.5	-9.5	-1.0	32	107	90	6	33.3	11.8	20.1	27.0	33.9	15	86	26	48
Average	291.35	102.3	11.56	35.94	86.99	11.49	92.58	7.0	78.4	-9.1	-2.88	31.10	108.1	88.37	6.0	31.28	11.43	20.2	26.97	33.56	13.6	86.6	25.96	47.8
	F°	C°	C°	C°	C°	F°	F°	C°	C°	inches	inches	Lbs	Lbs	F°	C°	C°	F°	F°	F°	F°	C°	C°	Inches	F°
C° Reduced To F°		34.6	52.0	96.4	188.2				44.6	177.1					42.9	88.3					60	102.6		

TABLE 10 LOG OF TEST, MARCH 8, 1906

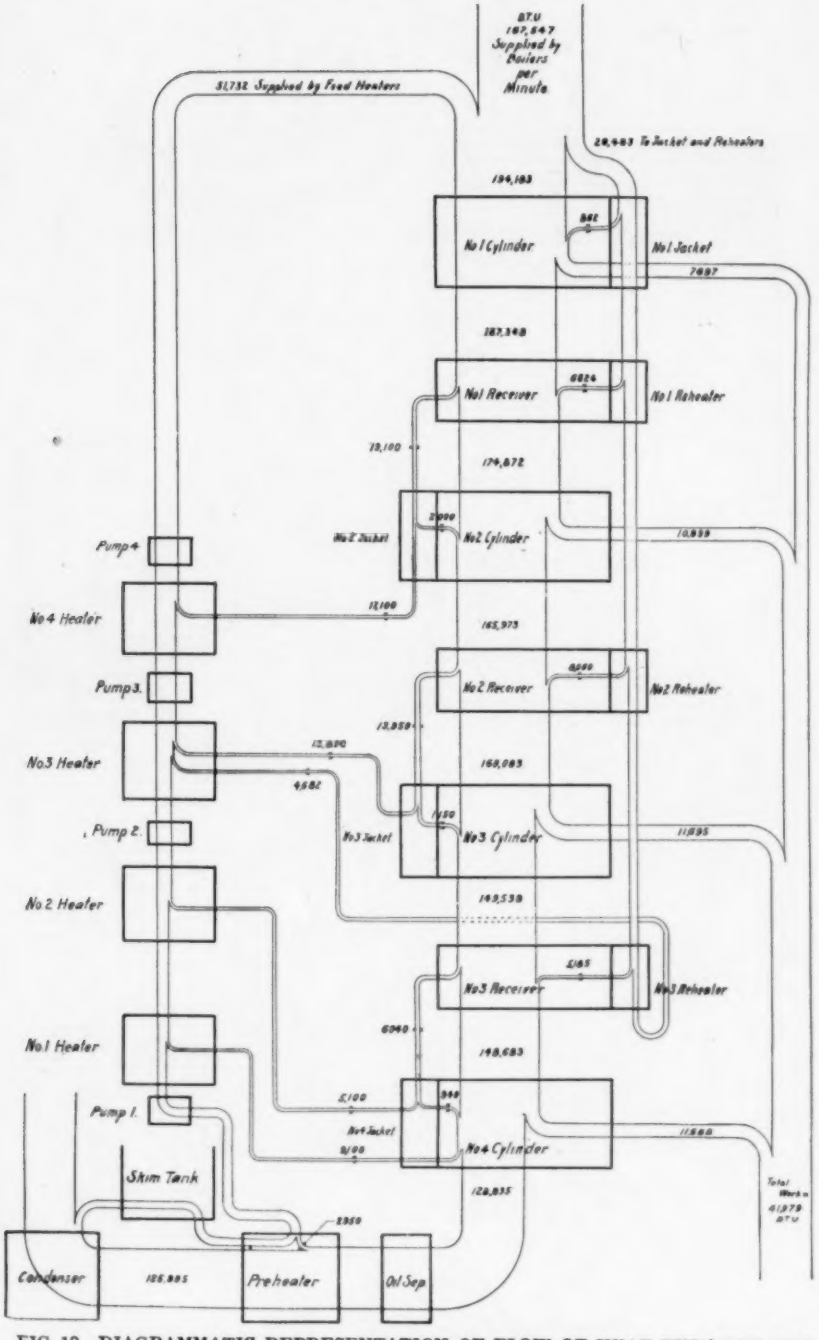
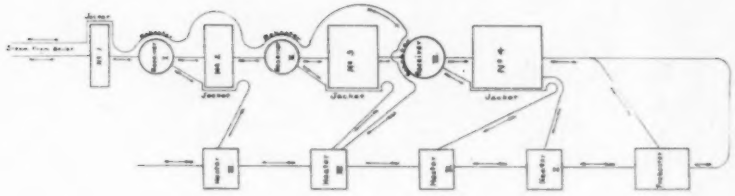


FIG 12 DIAGRAMMATIC REPRESENTATION OF FLOW OF HEAT THROUGH THE ENGINE (APPROXIMATE DISTRIBUTION)



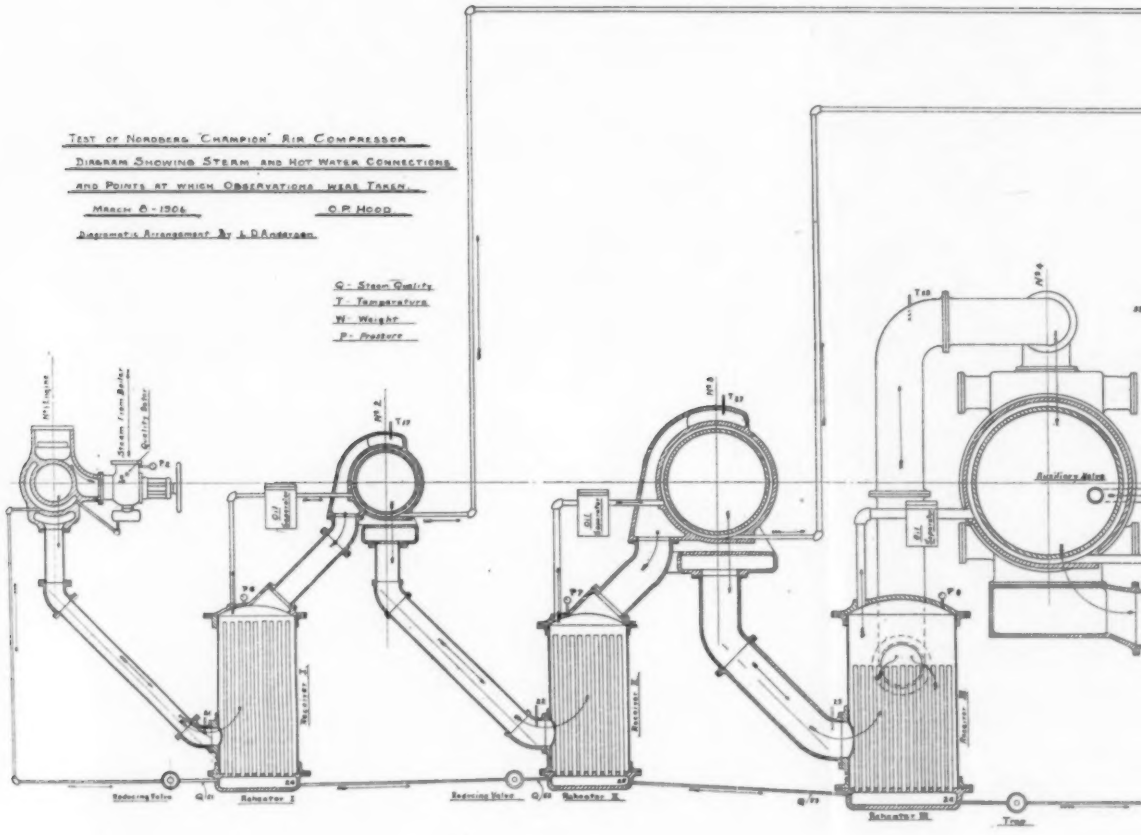
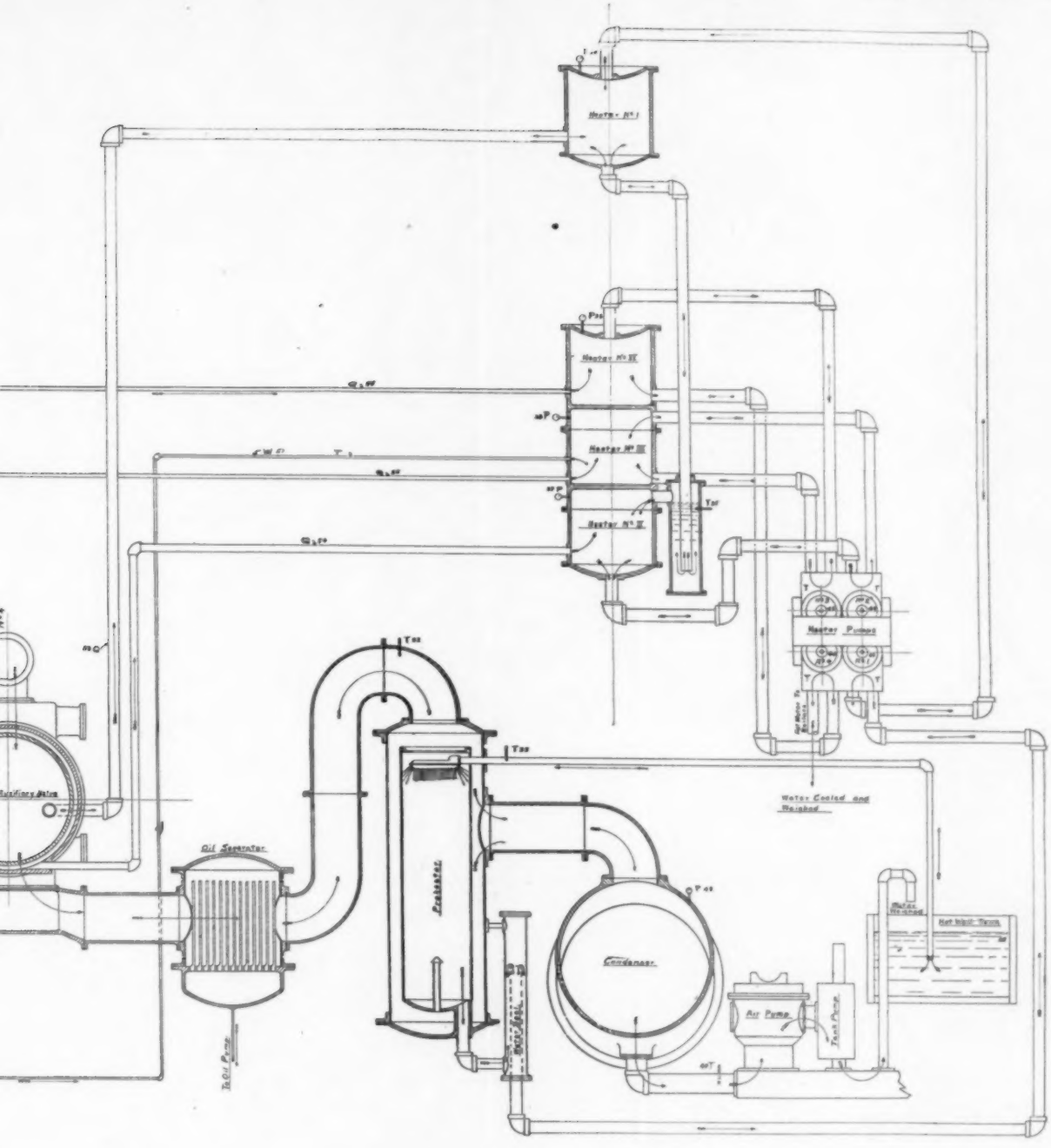


FIG. 11 DIAGRAM SHOWING STEAM AND HOT WATER CONNECTIO



CONNECTIONS AND POINTS AT WHICH OBSERVATIONS WERE TAKEN

AUXILIARY PIPING

14 Air chambers on all pump lines are piped to receive compressed air when needed. All heaters are connected by small piping to the condenser to remove air which occasionally traps in them. All water jackets about air cylinders are tapped at the highest point by a system of piping, leading to the intercooler and are continuously bled to prevent pocketing of air. Steam taken from receivers to jackets passes oil separators dripped into the receivers which drain through blow off pipes. Oil for lubrication is supplied through a system of piping. Electrical connections are provided for indicators at each cylinder end.

RELATION OF PARTS

15 The whole machine occupies a space 45 x 56 feet in one end of a building, there being on the same level with the four engines the intercooler and skimming tank, while below the floor are receivers, governor mechanism, auxiliary pumps, oil separator, and traps. The condenser and preheater extend from the basement through and above the main floor.

CONCERNING TESTS

16 The feed water leaving the last pump under boiler pressure and at a temperature of 334.5 degrees was cooled by throttling through cast radiators immersed in cold water and delivered to weighing tanks holding about 3000 pounds each.

17 The duty was determined in a run of ten hours on March 8, by weighing the cooled water from the heaters and taking indicator cards from the eight steam and air cylinders with sixteen indicators electrically connected so that simultaneous cards were obtained. To determine the distribution of heat a similar test of five hours' duration was run on March 17, when the water coming from the condenser was weighed, as well as that from the heaters, to determine the per cent added in the heaters. To determine what proportion of this addition was abstracted from each receiver it was necessary to adopt some method which would determine the quantity without taking anything from the system or interfering with the flow to any extent. Into each line sending wet steam to either reheater or feed heater a large separator was placed, the outlet being provided with a throttling calorimeter. This arrangement is shown in Fig. 20.

18 A glass on the side of the separator showed the rate at which water accumulated. When a small amount had accumulated it was

allowed to continue its normal journey to the heater by discharging through a three-way-cock.

19 The quality of the very wet steam supplied to each place was in this way determined and the weight flowing to each heater computed from the observed temperature rise in feed heaters. This method produced no disturbance of temperatures in the feed heaters, but the numerous calorimetric determinations together with the cumulative errors of such a method make the results approximate.

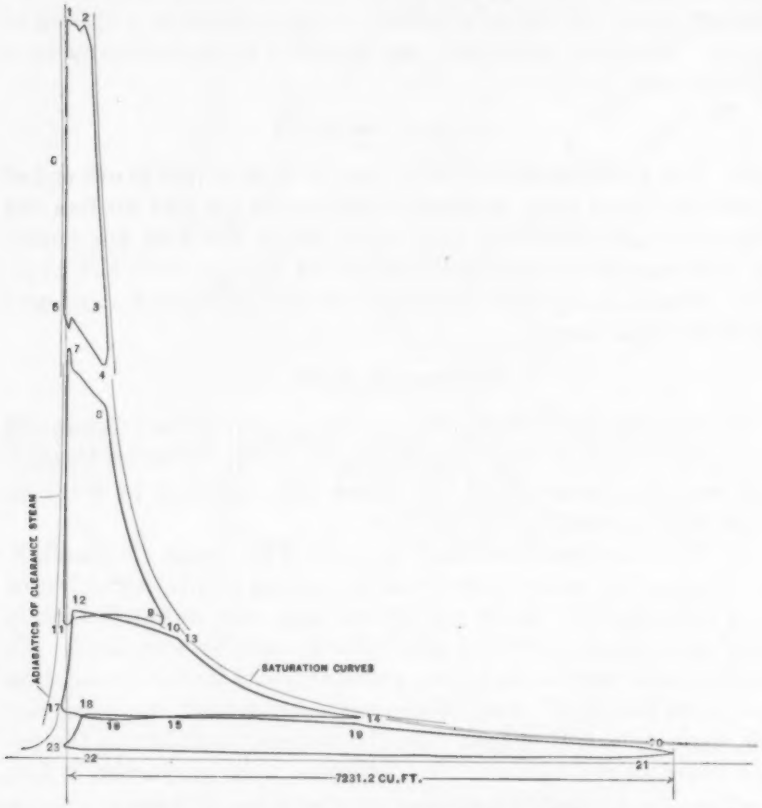


FIG. 13 COMBINED COMPOSITE CARDS SHOWING PRESSURES AND VOLUMES OF CYLINDER FEED PER MINUTE
HORIZONTAL SCALE 1″=498 CU. FT. VERTICAL SCALE 1″=15 LBS. PER SQ. IN.

PERSONAL

20 To Mr. F. W. Denton, General Manager Copper Range Consolidated Company, thanks are due for permission to publish these results and for interest shown in the work.

21 For aid in many ways in the preparation for and conduct of these several tests, acknowledgment should be made of valuable services rendered by Mr. R. R. Seeber, Chief Engineer Champion Copper Company; Mr. R. H. Corbett (Member), representative of the Nordberg Manufacturing Company; Assistant Professor, Geo. L. Christensen. Michigan College of Mines; Mr. Wm. Richards, Master Mechanic; Mr. W. Stevens, Foreman; Engineers D. McLeod and D. Toms, students of the Michigan College of Mines, and others who acted as observers, and to Mr. .A G. Andrew, Jr., who was employed in working up results and making drawings.

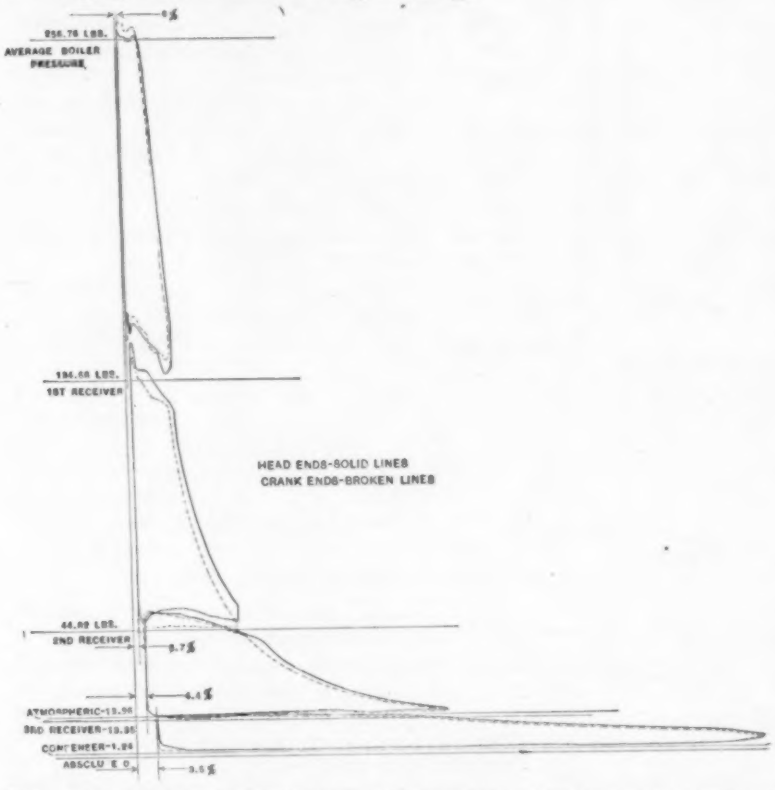


FIG. 14 COMBINED SIMULTANEOUS CARDS FROM HEAD AND CRANK ENDS OF STEAM CYLINDERS
VERTICAL SCALE 1″=15 LBS.

EXHIBITS

22 Fig. 11 shows a diagrammatic section through the cylinders and heaters illustrating the path of the steam and feed water and indicating the points of observation involved in this test. The numbers cor-

respond to similar numbers in the several logs. The observations made in the test of March 8 are shown in Tables 5 and 10. The feed water record of both tests is shown in Table 9.

Tables 6 and 7 show the log of the test of the 17th, when only so many of the points of observation were included as to show the comparableness of the conditions to those of the 8th. The tabulation of

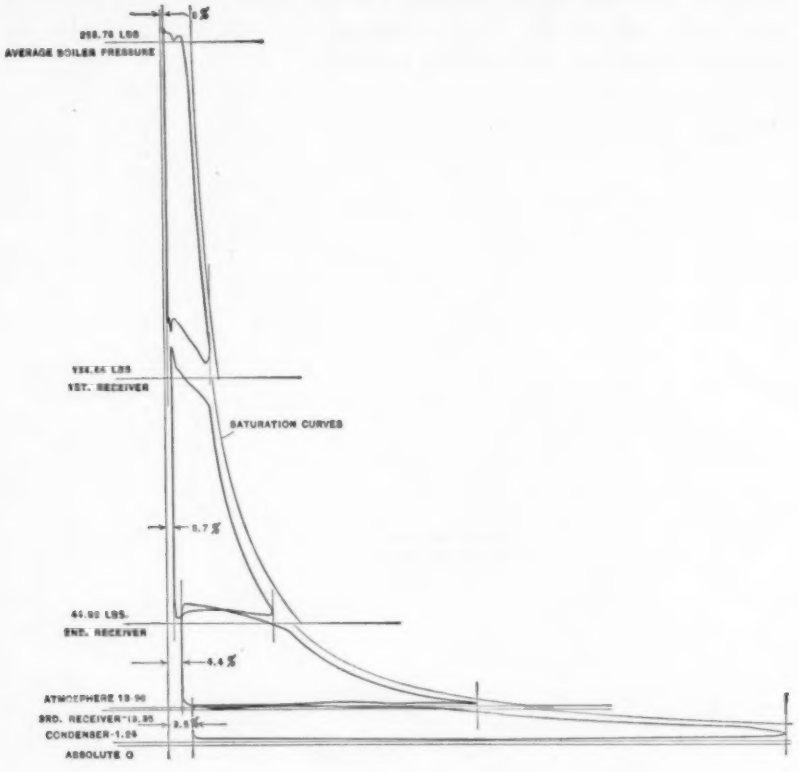


FIG. 15 COMBINED COMPOSITE CARDS FROM STEAM CYLINDERS
VERTICAL SCALE 1"=15 LBS.

the results from indicator cards from steam, air and auxiliary cylinders is shown in Figs. 1, 2, 3, 4. Fig. 8 shows the observations made to determine the quality of wet steam flowing to the several reheaters, etc., and used in computing the approximate distribution of heat through the engine.

DIMENSIONS

Number of cylinder	1	2	3	4
Diameter	14.52″	22.01″	38.00″	54.00″
Length of stroke	48.00″	48.00″	48.00″	48.00″
Diam. of piston rod crank end	3½″	3⅜	3½″	3½″
Net area of piston head end	165.58″	380.48″	1134.10″	2290.20″
crank end	156.64″	371.54″	1125.16″	2281.20″
Clearance	6.0%	5.7%	4.4%	3.5%
Cylinder volume head end	7948	18,263	54,437	109,900
crank end	7519	17,833	54,008	109,500
Vol. plus clearance head end	8425	19,300	56,830	113,780
crank end	7996	18,870	56,400	113,350
Cylinder ratios	1.000	2.330	7.01	14.19
Horse power const. head end	1.143	2.626	7.828	15.808
crank end	1.081	2.564	7.766	15.746
Number of air cylinder	1	2	3	4
Diameter	37.22″	23.07″	23.02″	36.74″
Length of stroke	48	48	48	48
Diam. of piston rod head end	3½″	3½″	3½″	3½″
crank end	3½″	3½″	3½″	3½″
Net area of piston hd. end sq.in.	1079.40	409.25	407.43	1051.20
crank end	1078.00	407.87	406.06	1049.80
Clearance ..... head end	2.65%	1.92%	1.92%	2.65%
crank end	2.57%	1.74%	1.74%	2.57%
Air cylinder ratio	1 to 2.61			

	Diameter	Stroke
Air pump	20″	12 31/32″
Circulating pump	10⅞″	19½″
Tank pump	5″	13″
Intercooler pumps	5½″	11 13/16″
All feed pumps	6″	7 5/16″

Main steam pipe 5″double extra heavy Condenser 2700 sq. ft. of cooling surface.

TOTAL QUANTITIES, TIME, ETC.

Duration of test	10 hrs.
Water delivered from last heater as boiler feed	117,950 lbs.
Moisture in the steam near the throttle	5.74%
Factor of correction for quality of steam	94.26
Total dry steam used	111,180 lbs.

HOURLY QUANTITIES

Feed water per hour	11,795 lbs.
Dry steam per hour	11,118 lbs.

PRESSURES, TEMPERATURES, ETC.

Steam gage pressure near throttle		242.80 lbs.
Barometric pressure		28.50 ins.
Pressure in receiver	First	120.70 lbs.
	Second	30.80 lbs.
	Third	−1.24 ins.

Vacuum in condenser		25.95 ins.
Absolute pressure in condenser		1.25 lbs.
Pressure in steam jackets	No. 1	242.00 lbs.
	No. 2	120.00 lbs.
	No. 3	30.00 lbs.
	No. 4	−1.24 ins.
Pressure in heaters	No. 1	209.00 lbs.
	No. 2	104.00 lbs.
	No. 3	73.00 lbs.
Quality of steam in receivers	No. 1	100%
	No. 2 Superheat	17°
	No. 3 Superheat	9°

TEMPERATURES

Temperature of steam fed to No. 1 engine	403.4°
Temperature of steam leaving receiver No. 1	351.2°
Temperature of steam leaving receiver No. 2	291.2°
Temperature of steam leaving receiver No. 3	216.0°
Temperature of exhaust entering preheater	114.9°
Temperature corresponding to condenser pressure	109.6°
Temperature of water fed to preheater	92.58
Temperature of water fed to heater No. 1	114.3°
Temperature of water fed to heater No. 2	173.1°
Temperature of water fed to heater No. 3	202.0°
Temperature of water fed to heater No. 4	269.7°
Temperature of water leaving heater No. 4 as boiler feed	334.5°

HEAT QUANTITIES

Heat units per pound of steam, pressure 256.8 abs.	1204.98 B. T. U.
Heat units per pound of steam supplied to engine	1157.46 B. T. U.
Heat units per pound of feed returned by engine	305.14 B. T. U.
Heat units per pound of steam charged to engine	852.32 B. T. U.

SPEED

Total revolutions in ten hours	34,167
Revolutions per minute	56.945
Piston speed in feet per minute	455.5
Speed compared to contract speed	74%

POWER

Cylinder	1	2	3	4
Indicated horse power developed in steam cylinders	181.47	256.96	275.71	275.56
Indicated horse power used in the air cylinders	220.04	222.12	226.20	214.84

Total indicated horse power, steam cylinders	989.7 H. P.
Total horse power used in air cylinders	883.2 H. P.
Total indicated horse power of auxiliaries	11.0 H. P.
Horse power representing friction of the machine	95.5 H. P.
Per cent of friction	9.65%
Mechanical efficiency engine and compressor	90.35%

STANDARD EFFICIENCY RESULTS

Heat consumed by engine per hour per I H. P. ..... 10,157 B. T. U.
Heat consumed by engine per hour per B. H. P. ..... 11,382 B. T. U.
Equivalent standard coal consumption per hour assuming calorific value of coal such that 10,000 B. T. U. are imparted to the boiler per pound coal per I. H. P. .....1.016 lbs.
coal per B. H. P. .....1.138 lbs.
Dry steam per I. H. P. per hour .....11.23 lbs.
Dry steam per B. H. P. per hour .....12.58 lbs.
Heat units consumed per minute per I. H. P. ..... 169.29 B. T. U.
Heat units consumed per minute per B. H. P. ..... 189.70 B. T. U.
Efficiency of theoretical Carnot Cycle between the temperature of incoming steam and the temperature corresponding to pressure in the condenser .....34.0 %
Actual heat efficiency attained by this engine 25.05%
Relative efficiency compared with Carnot cycle 73.69%
Relative efficiency compared with Rankine cycle .....88.2 %

DUTY

Duty in foot-pounds of work developed per million heat units supplied to the engine .....194,930,000 foot-pounds

This engine establishes a new low record for the heat consumed per hour per I. H. P., being 9% lower than that used by the Wildwood pumping engine reported in 1900.

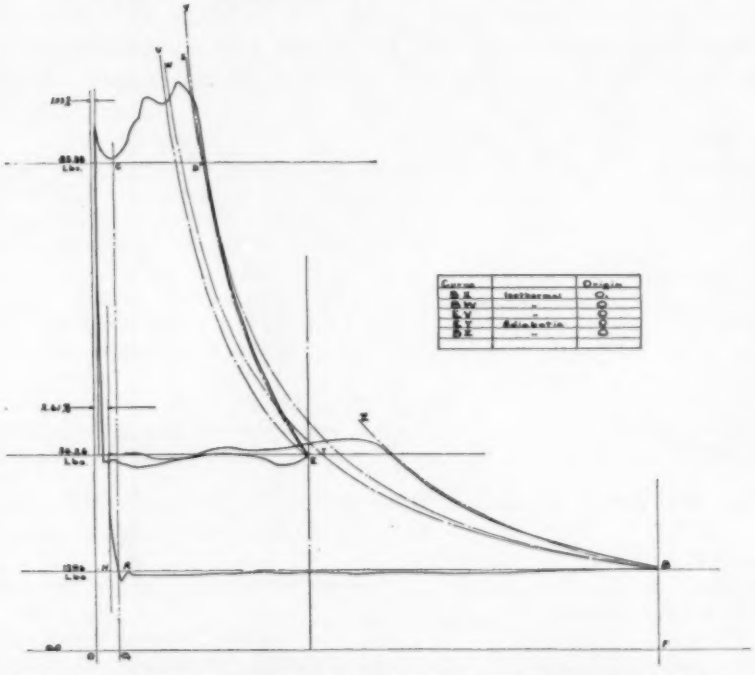


FIG. 16 COMBINED COMPOSITE AIR CARDS WITH REFERENCE CURVES
VERTICAL SCALE 1"=10 LBS.

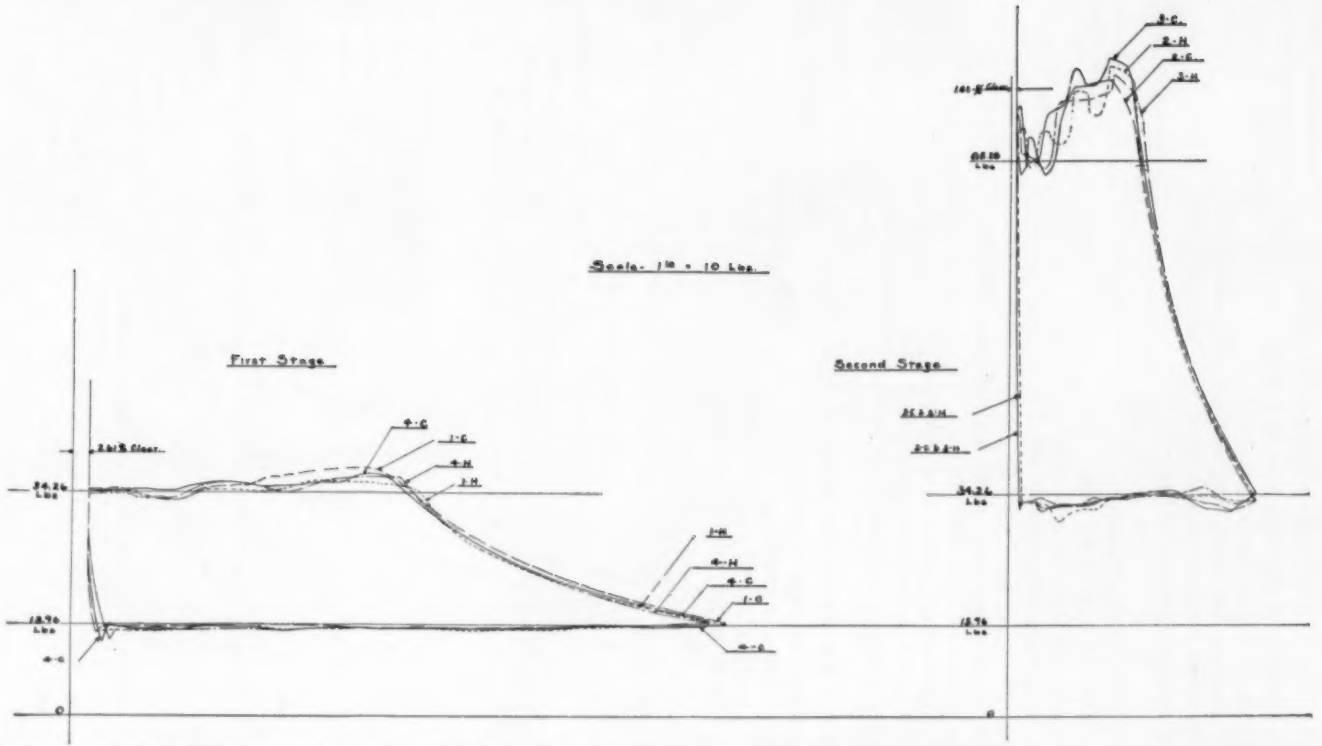


FIG. 17 SIMULTANEOUS CARDS TO COMMON SCALE FROM HEAD AND CRANK ENDS OF COMPRESSION CYLINDERS, MARCH 8, 1906

23 The path followed by the steam through the several devices is shown in Fig. 11, while Fig. 12 shows in a diagrammatic way the flow of heat. The heat used by the engine per minute was carried by 196.578 pounds of wet steam of quality 94.26% having a value of 1157.46 heat units per pound, which weight was returned to the boilers with a heat content of 305.14 heat units, making a net expenditure of 852.32 B. T. U. per pound or a total of 167,547 B. T. U. per minute.

24 The distribution of this heat is approximated in Fig. 12 and Fig. 18. The test of the 17th showed the weight coming from the condenser, when corrected for the difference in the two tests in the heat added in the No. 4 heater, to be 69.2 % of that charged to the engine. Beginning with this quantity of 136 pounds per minute and making the additions of weight necessary to raise the feed water to the temperature observed in each heater by the addition of wet steam of the quality determined by the several calorimeters, the computed weight going from No. 4 heater would be 8.3 pounds in excess of the known weighed amount, although the additions of heat by this computation would be in excess only 595 B. T. U. in 51,733.

25 An adjustment of the several computed weight additions in each heater was, therefore, necessary and each was multiplied by 88 % on the assumption that the cumulative errors were equally distributed. This gives the following distribution of weight used per minute.

	Pounds
Steam fed to engine per minute (weighed)	196.5
Steam sent to reheater line	20.2
Steam sent through No. 1 cylinder	176.3
Steam taken from No. 1 receiver	14.9
Steam sent through No. 2 cylinder	161.4
Steam taken from No. 2 receiver	11.0
Steam sent through No. 3 cylinder	150.4
Steam taken from No. 3 receiver	4.9
Steam sent to No. 4 cylinder	145.5
Steam taken from No. 4 cylinder during expansion	7.3
Steam condensed in the preheater	2.2
Steam sent through condenser (weighed)	136.0

26 Those adjusted weights when applied to the quantity in each feed water heater are as follows:

	Pounds
Feed water sent to preheater per minute	136.0
Added in the preheater	2.2
Feed water sent to No. 1 heater	138.2
Added in No. 1 heater from No. 4 cylinder	7.3

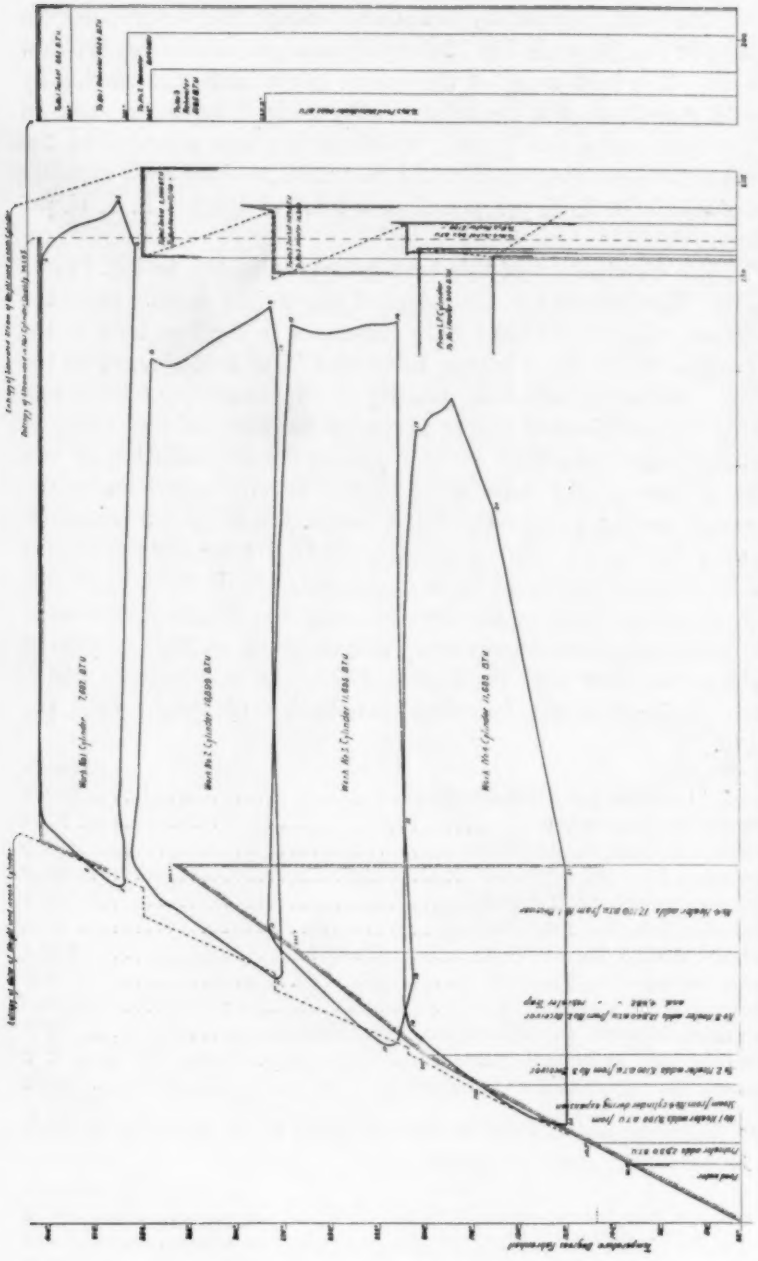


FIG. 18 TEMPERATURE ENTROPY DIAGRAM WITH APPROXIMATE DISTRIBUTION OF HEAT USED PER MINUTE, ENGINE QUADRUPLE EXPANSION CYLINDERS 14.5", 22", 38", 54" x 48" STEAM PRESSURE 256.8 ABS. 56.945 I. P. H.

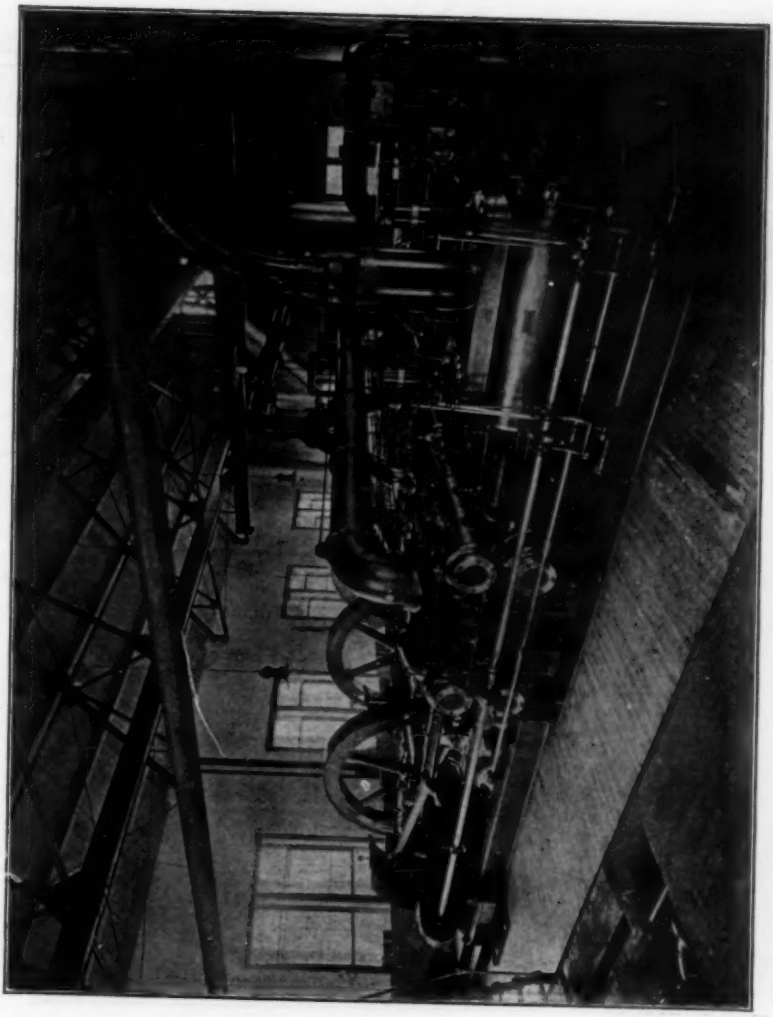


FIG. 19 NORDBERG QUADRUPLE EXPANSION TWO STAGE AIR COMPRESSOR AT CHAMPION MINE, PAINESDALE, MICH.

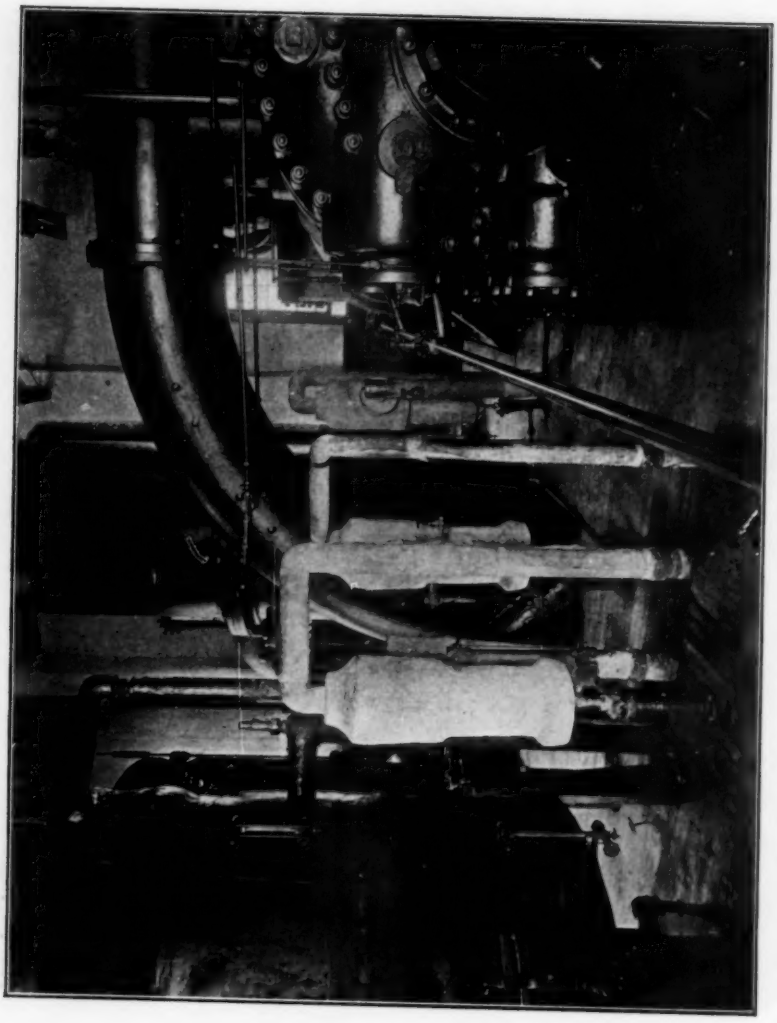


FIG. 20 FEED WATER HEATERS (ON THE LEFT) AND SEPARATING CALORIMETERS USED IN DETERMINING QUALITY OF WET STEAM USED FOR FEED HEATING

	Pounds
Feed water sent to No. 2 heater	145.5
Added in No. 2 heater from No. 4 jacket	4.9
Feed water sent to No. 3 heater	150.4
Added in No. 3 heater from No. 3 jacket	31.2
Feed water sent to No. 4 heater	181.6
Added in No. 4 heater from No. 2 jacket	14.9
Feed water sent to boilers (weighed)	196.5

27 The heat given up to each jacket was computed from the quality determinations on each side of the jacket and the weight flowing to the several heaters.

28 No measurement of the radiation from the machine was attempted because of the complication incident to maintaining the several pressures required and because the distribution of perhaps 2% of the total heat used through the numerous devices was hardly warranted.

29 One set of simultaneous indicator cards, near the mean in H. P., was selected and combined, the cards from the two ends of the cylinder superimposed as shown in Fig. 14, and from these a composite card was constructed as a mean shown in Fig. 15.

30 In developing the temperature entropy diagram the composite card Fig. 13 was redrawn, eliminating the clearance volume of steam.

31 The entropy diagram Fig. 18 shows in a graphical manner the heat transferred from the expansion side to the feed heating side of the diagram and the tendency of this regenerative feed heating method to produce a net diagram available for work approximating the rectangle of maximum efficiency.

32 To avoid the confusion of many superimposed areas, that portion of the diagram representing the heat used in the reheater line has been moved to the right a distance equal to its width. The small figures surrounding the areas representing heat transferred to work correspond to those on the pressure-volume diagram, Fig. 13.

RESULTS FROM THE AIR COMPRESSING CYLINDERS

33 The air compressing is accomplished in two low pressure and two high pressure cylinders, each double acting. The four cards showing the performance of the same function were superimposed as in Fig. 17 and a composite was drawn representing the mean condition shown in Fig. 16.

34 The volumetric efficiency is 98.43% and would require a speed of 77.3 r. p. m. to deliver the required 9000 cu. ft. of air per minute. The actual H. P. shown by the air cards is 883.2 H. P. while the same weight of air compressed isothermally would require but 731.3 H. P.,

showing an efficiency of the two stage compression compared with isothermal of 82.8%.

35 The temperatures of air and jacket water were as follows:

	Low Pres.		High Pres.	
Cylinder	4	1	2	3
Temperature of air entering	31	31	53.2	52.8
Temperature of air leaving	188.2	183.7	224.6	227.0
Temperature difference	157.2	152.7	171.4	174.2
Temperature of water entering jacket	42.8	58.2	73.0	82.8
Temperature of water leaving jacket	58.2	73.0	82.8	96.4
Temperature difference	15.4	14.8	9.8	13.6

36 The water was supplied to the several jackets in series through a shunt circuit from a line supplying water to the intercooler.

BOILER AND SETTING

Improved Design for Use with Bituminous Coal

By A. BEMENT, CHICAGO, ILL.
Member of the Society

1 Fig. 1 shows an elevation and section of a modified design of boiler equipped with a chain grate stoker, although any other stoker machine would be applicable.

2 The principal objects to be secured in this design are:

a The attainment of a perfect and smokeless combustion;

b The full utilization of the boiler heating surface.

3 The first requirement is secured by the location of a tile furnace roof, which is supported by the boiler tubes of the lower row. The individual refractory tiles used in the formation of this roof are illustrated in detail in Fig. 2 and by a vertical cross-section, Fig. 3. The effect of the presence of this tile roof is to prevent the flow of unburned gases among the tube surfaces of the boiler, and to insure that they travel a considerable distance before the heating surface is reached, during which time these gases and the air present therewith may become sufficiently mixed together to insure entire combustion. The particular form of stoker shown, that of the chain grate, owing to the fact that the fuel is fed only in a horizontal line, and for which reason sudden and irregular charges of fuel cannot enter the fire, insures the apparatus to be entirely smokeless. It might be styled smoke-proof, if this expression is permissible in this connection. When other styles of stoker machines are used under such roof, the attainment of complete combustion is dependent upon careful manipulation of the machine and fire, because the capacity of the tile roof furnace herewith illustrated is only sufficient to properly mix together the air and gases which flow from a chain grate fire. Therefore, in other forms of stokers, it is necessary for the uniformity in feed of coal and condition of fire to be equal to that secured with chain grates, for complete combustion to be effected. A considerable number of such tile roof furnaces are now in successful operation.

To be presented at the New York Meeting (December, 1906) of The American Society of Mechanical Engineers, and to form part of Volume 28 of the Transactions.

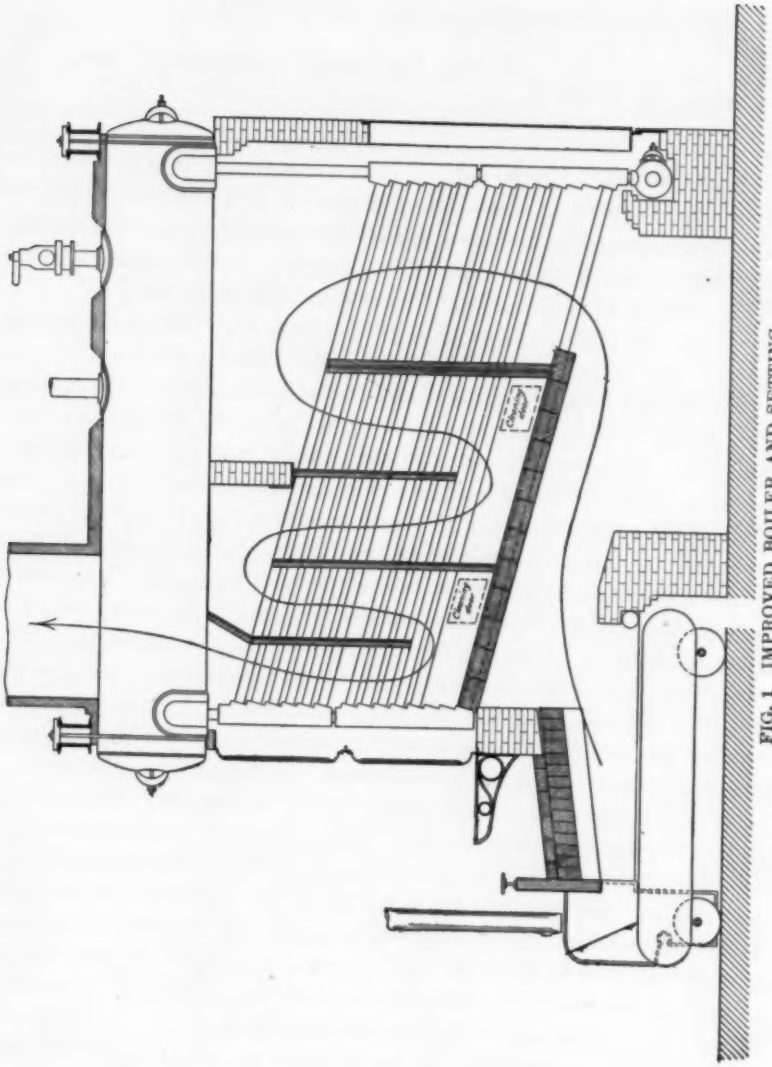


FIG. 1 IMPROVED BOILER AND SETTING

4 To insure that all of the boiler surface shall be usefully employed the gases are led over the whole portion of it by means of passages of less area than are commonly used. It is the writer's observation that in many boilers various corners and other portions are not acted upon by hot gases, because the decreasing volume due to the gases becoming cooled is not equal to the capacity of the passage, for which reason in this design the additional baffles are employed. The decrease in size of these passages, however, are not in the same ratio as the reduction in volume of gas. Proportioning the passages according to the volume of the gases in the different parts of the boiler would have required at the inlet to the tube surface a space much larger, with the effect of very materially reducing the length of the tile roof. Therefore the compromise illustrated is adopted.

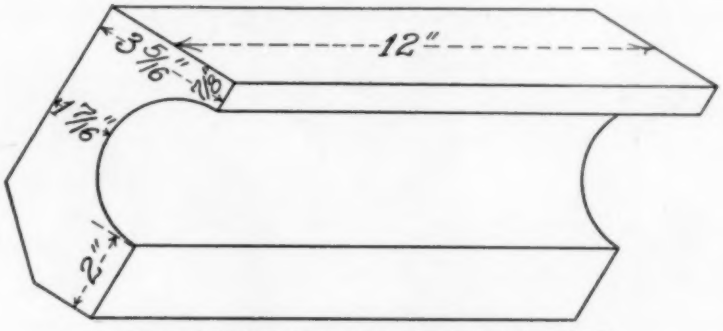


FIG. 2 REFRACTORY TILE FOR FURNACE ROOF

5 A space at the bottom of the boiler above the tile roof equal to that which would ordinarily be required by the second and third tier of tubes, is left vacant for the purpose of accumulating dust, which may be removed through cleaning doors in the side wall of the setting. The lower tubes supporting the tile roof are of 3.5 inches diameter, and of a heavier gage than the 4-inch tubes above. The smaller diameter is employed for the purpose of affording greater space for the necks of the tiles than is obtainable with the 4-inch tubes.

6 The contracted passages among the tube surfaces of this boiler necessarily produce a high resistance, and for this reason a strong draft is required, and this appears to be true of any boiler when arranged so that all of the heating surface is utilized. According to the author's present conclusions, a combination of forced and induced draft affords means for the production of the best obtainable combustion, particularly so with the chain grate stoker. The induced draft

may, of course, be obtained either with fan or chimney. The office of the forced draft is to move the gases as far as the furnace chamber, from which point they flow among the heating surfaces of the boiler to the chimney by means of the power of induced draft. Therefore, the influence of the forced draft extends from below the grate to the furnace chamber, while the power of the induced draft extends from the chimney among the heating surfaces to the point in the furnace, at which that of the forced draft ceases. Under such conditions the pressure of the gases in the furnace is the same as that of the atmosphere. This prevents a portion of the air leakage, which, under other conditions, would flow into the furnace chamber by way of openings at the stoker through the brick walls and elsewhere. By manipulating the intensity of the forced and induced draft, a balance pressure may be obtained in the furnace chamber when varying amounts of coal are being burned. Therefore, this draft system operates not only to over-

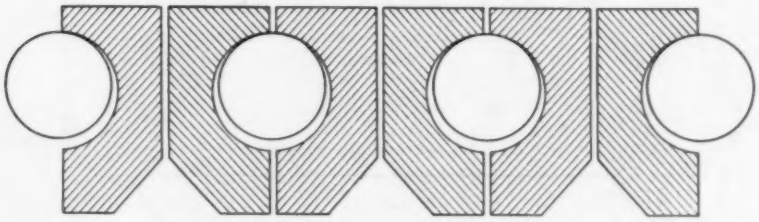


FIG. 3 SECTION SHOWING FURNACE ROOF

come the resistance due to the passage among the heating surfaces, but also insures complete combustion with a smaller air supply than would be the case with induced draft alone. This condition has been referred to as that of balanced draft. In this connection it may be well to call attention to the fact that forced draft cannot be depended upon to compel the flow of gases among the heating surfaces to any great extent, because when the pressure in the furnace chamber becomes greater than that of the atmosphere, the flames and fire will blow out through the doors, cracks, or other openings.

7 Figures are as yet not available, showing the exact effect of this particular arrangement of baffles, but results in a similar case of baffling[1] will serve to indicate that a high efficiency is attainable.

8 Data is, however, available, showing the effect due to the use of a balanced draft. The average of four simultaneous tests with a

[1] Trans. A. S. M. E., Vol. 26, p. 619, and Trans. A. S. M. E., Vol. 26, p. 418.

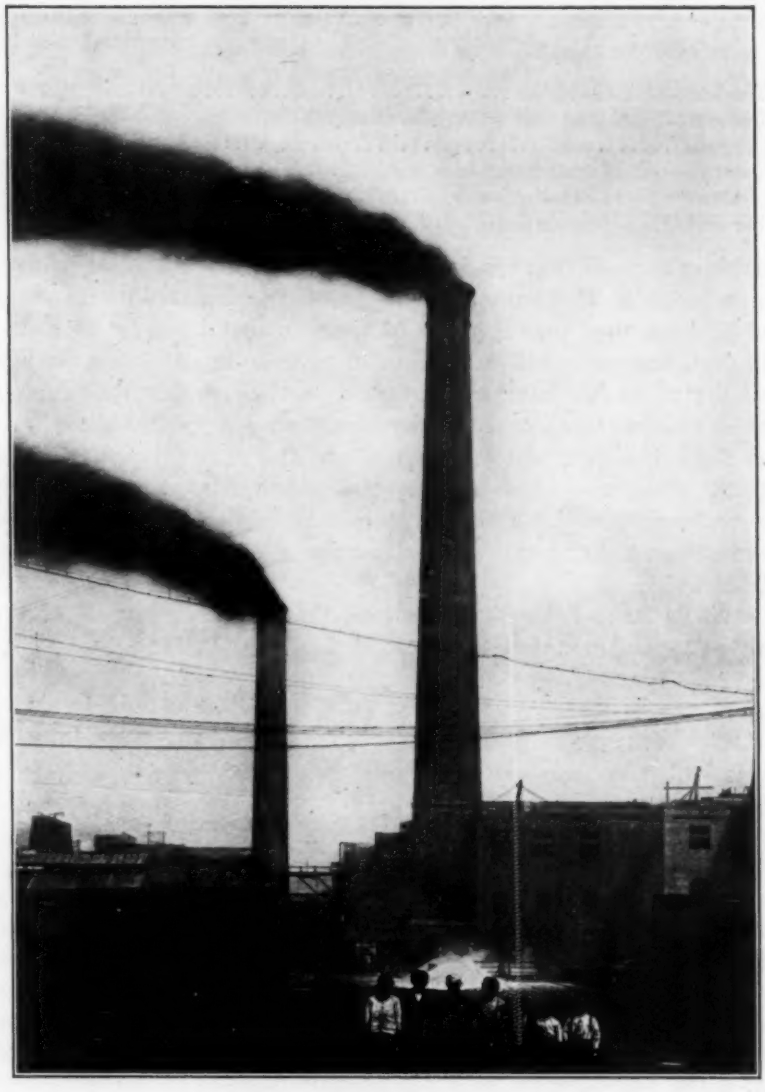


FIG. 4

CHIMNEY OF A. & CO. IN FOREGROUND; WATER TUBE BOILERS AND CHAIN GRATES WITHOUT TILE ROOF. CHIMNEY IN BACKGROUND THAT OF B. & CO.; WATER TUBE BOILERS AND MURPHY FURNACE

chain grate stoker located under a Babcock & Wilcox boiler gave the following average results:

	BOILER A NATURAL DRAFT	BOILER B FORCED DRAFT
Thickness of fire in inches	7.0	7.0
Per cent of coal used that would pass through ½ inch round screen	13.1	13.1
Total strength of draft in inches of water	0.389	0.380
Draft over fire in inches of water	0.389	0.00
Per cent CO_2 in furnace gases	5.03	7.32

Each of these tests covered a period of four hours and measurements were made at 15-minute intervals. Coal from exactly the same lot of fuel was used in each series of tests, so that a test for each kind of draft was made with a uniform lot of coal, thus avoiding the possibility of the fuel having an influence on the results. With each of these stokers there was a considerable opening at the end of the grate at the bridgewall, which, however, was the same in each series of tests. Otherwise a higher per cent of carbon dioxid would probably have been realized. The tests on each boiler were conducted at the same time, and alternating wheelbarrows of coal were supplied to the boilers.

9 So far as the author is aware, there are no features of the above apparatus which are patented.

APPENDIX

10 Since the above was prepared, it has been considered desirable to offer some examples to illustrate the performance of water tube boilers that are fitted with the tile furnace roof recommended in this paper, as compared with similar boilers without the tiles, from the standpoint of smoke, chain grate stokers being used in each case; also to illustrate the result secured by careful manipulation of Murphy stokers under the same type of water tube boiler. To this end the Fuel Engineering Company of Chicago, made an examination of certain plants in the same city, and the following quotation is from its report signed by Edward H. Taylor, Secretary, in which the owners of the two smoking chimneys in the photographic views are referred to as A. & Co. and B. & Co. to avoid undue publicity:

11 "A. & Co.'s plant (Fig. 4), located in the Stock Yards, has Aultman & Taylor boilers (Babcock & Wilcox type) served by chain grate stokers. There is no 'Dutch oven' or combustion chamber, the smoke going directly to the boiler. In the accompanying photograph showing two smoking chimneys, the one in the foreground is

that which serves these boilers and illustrates it at its normal appearance.''

12 Chicago Edison Company: A photograph is shown below of the station of this company, located at Harrison street and the river. The main boiler plant is served by the four large chimneys. The boilers are of the Heine type and are equipped with chain grate stokers the same as the plant of A. & Co. The essential difference between the

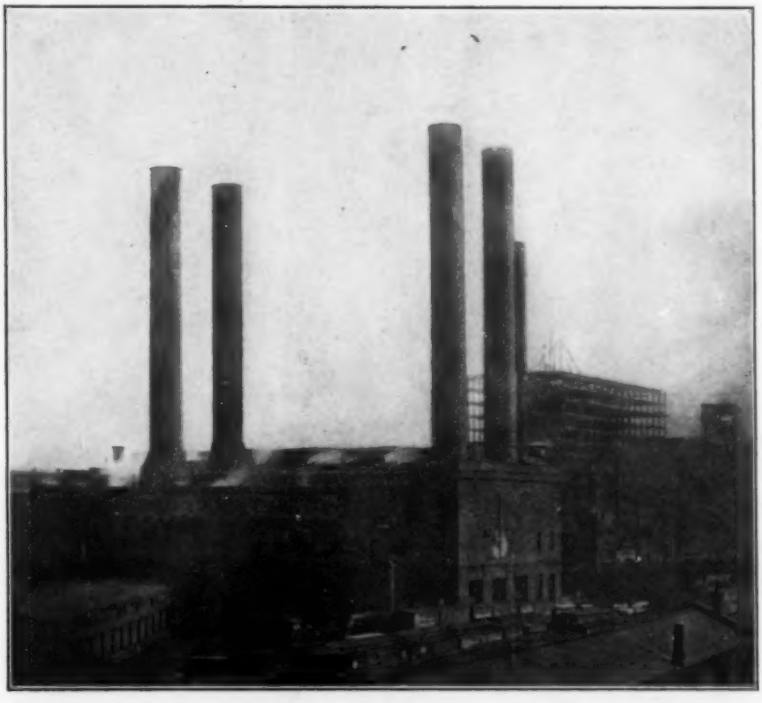


FIG. 5
PLANT OF CHICAGO EDISON CO. CHAIN GRATE STOKERS AND WATER TUBE BOILERS WITH TILE FURNACE ROOF

boilers of A. & Co. and those in this station, is that the Edison boilers are covered with sections of firebrick which extend from the front nearly to the back end of the boiler, so that the smoke gases pass along under these firebrick sections to the back end of the boiler instead of going immediately up to the front end as is the case with the boilers of A. & Co. The fifth chimney, or in other words, the small one shown in the view, is connected with other boilers which are seldom or

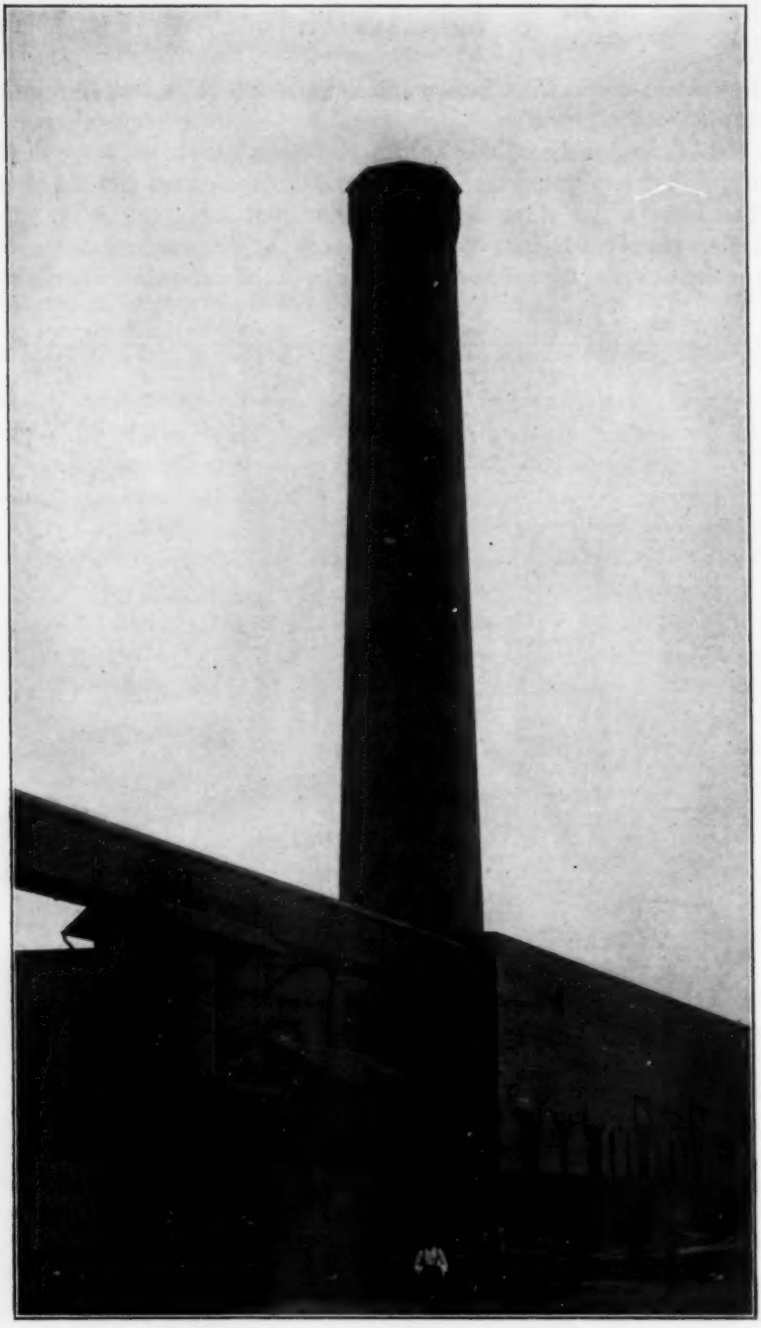


FIG 6

PLANT OF NORTHWESTERN ELEVATED RAILROAD COMPANY, OF CHICAGO. WATER TUBE BOILERS AND MURPHY FURNACES

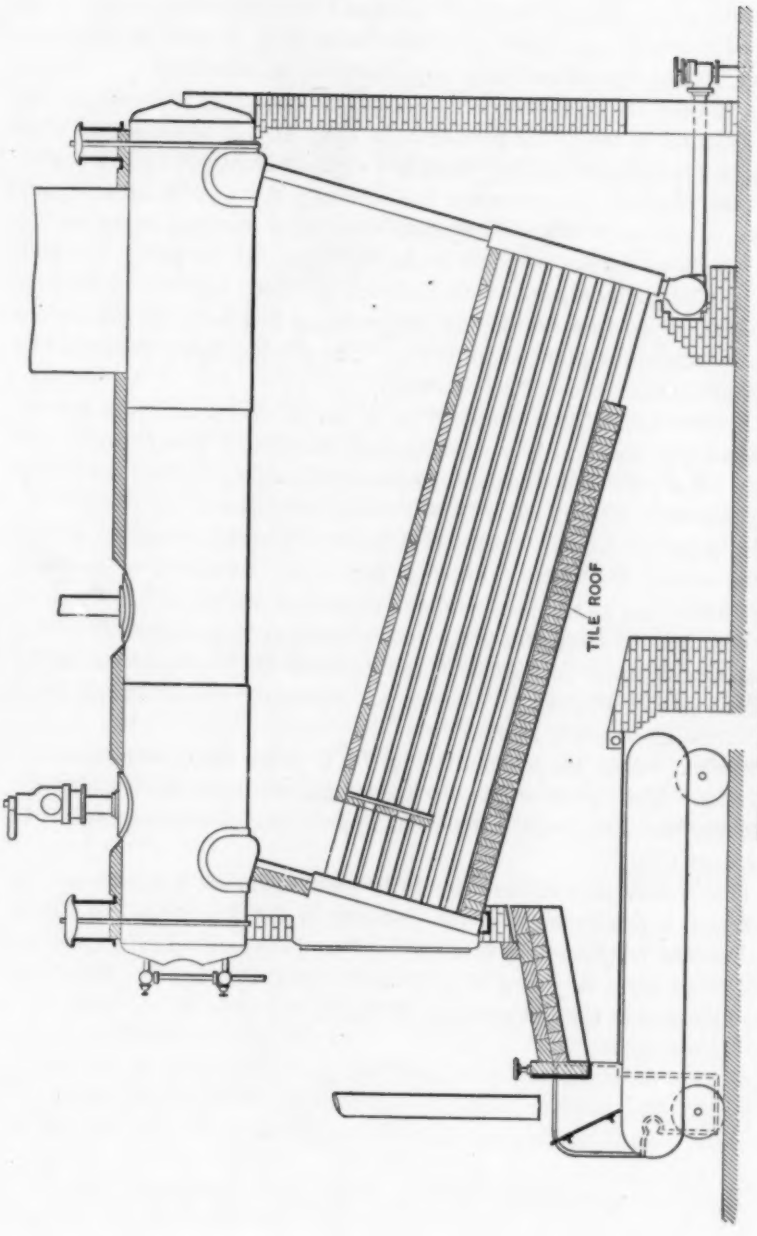


FIG. 7 BOILERS WITH TILE ROOF FURNACE
PLANT OF INTERNATIONAL HARVESTER COMPANY, CHICAGO

never in service. The above reference applies to the large chimneys and the appearance of these is indicated by this photograph, from which it would seem that the station was shut down; on the contrary, it is in operation every day, carrying a large load.

B. & Co.: One of the chimneys of this company is shown in the background of one of the photographs (Fig. 4). It is connected with Babcock & Wilcox boilers which are equipped with Murphy stokers and the photograph represents the chimney at its usual appearance.

Northwestern Elevated Railway. One of the accompanying photographs shows the power plant of the Northwestern Elevated Railway (Fig. 6), which is equipped with Babcock & Wilcox boilers and Murphy furnaces, or, in other words, the equipment is precisely like that in the above mentioned plant of B. & Co. The photograph represents the average appearance of the chimney.

Of these four plants, those of A. & Co., B. & Co. and the Northwestern Elevated Railway are of approximately 4000 boiler horse power each. The portion of the Chicago Edison Company's plant served by the four large chimneys, is 10,000 boiler horse-power capacity."

In addition to the above, Mr. W. L. Goddard, Engineer of the International Harvester Company has kindly furnished a sectional view of boilers in the McCormick Twine Mill, shown in Fig. 7, which he has changed from the usual vertical baffling to a single horizontal pass, and added a furnace roof, using a form of tile of his own design, differing from that of the author's. His letter which accompanied the drawing is quoted as follows:

"In our boiler arrangement (Fig. 7), the tiles have been on for 27 months. The furnaces are smokeless; gas samples taken every ten minutes for eight hours, with Orsat apparatus, gave an average of 13 per cent CO_2."

The effectiveness of the tile roof to prevent smoke is shown by Fig. 5, which is compared with the chimney in the foreground of Fig. 4, and further testified to by Mr. Goddard; and the result due to good and bad manipulation with a Murphy stoker is illustrated by Fig. 6 and the chimney in the background of Fig. 4.

STEAM PLANT OF THE WHITE MOTOR CAR

By R. C. CARPENTER, OF ITHACA, N. Y.
Member of the Society

1 The steam plant of the White Motor Car is an example of what can be accomplished on a small scale in the use of steam of high pressure and with a high degree of superheat in the steam engine and is consequently of interest to the mechanical engineer irrespective of its special application for the propulsion of motor cars. I take pleasure in presenting a description of this plant and also the results of a series of tests which I believe will prove of considerable interest to all engineers who are studying the question of the use of steam at high temperatures and pressures.

2 The White steam system was designed by R. H. White and has been successfully applied by the White Sewing Machine Company, during the last six years to several thousand motor cars; its essential and novel features are found principally in connection with the steam generator or boiler which is adapted to produce steam of high pressure and high temperature. The system is also of interest in the details of construction of its engine and in the means for automatically controlling the quantity, temperature and pressure of the steam produced.

3 It is a well recognized fact that the efficiency of a steam plant is increased by the use of steam at high temperatures and pressures and there are numerous tests on record which bear testimony to this fact. The development of the art of producing and using steam of high pressure and of a high superheat has been slow although probably continuous. So far as I can learn from correspondence, no boilers or engines exceeding 100 H. P. in capacity which are adapted to produce and use steam exceeding 300 lbs., pressure and 300 degrees superheat are built in this country at the present time. At least I

To be presented at the New York Meeting (December, 1906) of The American Society of Mechanical Engineers, and to form part of Volume 28 of the Transactions.

have been unable to find makers of both boilers and engines who could meet that kind of a demand. My own experience leads me to believe that the practical limit of pressure in steam plants of any considerable size in this country at the present time, taking into account boilers, engines, piping and valves, is not much above 200 lbs. per square inch. There are but few engines adapted for using steam with a superheat exceeding 200° F. This condition is doubtless accounted for by the existence of numerous practical difficulties, many of which relate to piping and valves and to the materials of construction which are now in ordinary use. There are also, no doubt, com-

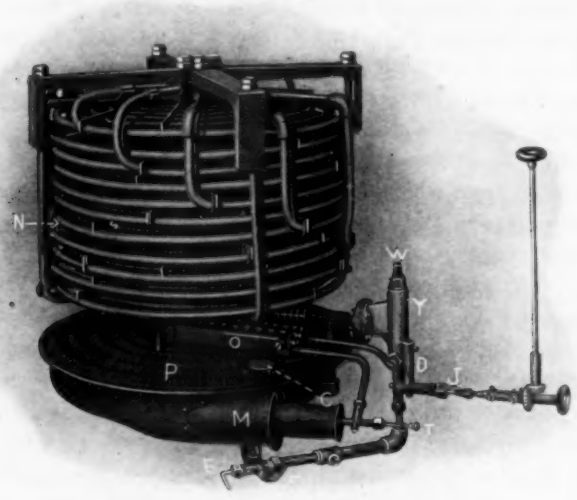


FIG. 1 THE WHITE GENERATOR
SHOWING ALSO THE PURNER, VAPORIZER, PILOT LIGHT AND GASOLENE CONNECTIONS WITH EXTERNAL CASING REMOVED

mercial difficulties of importance connected with the cost of manufacture and with the demand. I am of the opinion, however, that if the steam engine is to maintain its position as the principal power producing machine in competition with the internal combustion engine, the steam pressure and degree of superheat must be very largely increased over that in use at the present time. To meet these conditions there will be required many changes in design and construction of both engine and boiler which will probably require a long period of development to perfect.

4 The steam turbine which is already in extensive and successful use is well adapted for steam of high pressure and a high degree of

superheat, without change of design or construction, and will doubtless be used in a continually increasing proportion for producing power as the art of producing steam of high pressure and a high degree of superheat is developed.

THE BOILER

5 The steam generator or boiler of the White system is a series of horizontal coils connected so as to form a continuous tube through which all the water fed to the boiler and all the steam discharged from the boiler must pass. It is not provided with any reservoir either for water or steam. A perspective view of the boiler as used in the 1906 car is shown in Fig. 1 with the external casing removed. Its

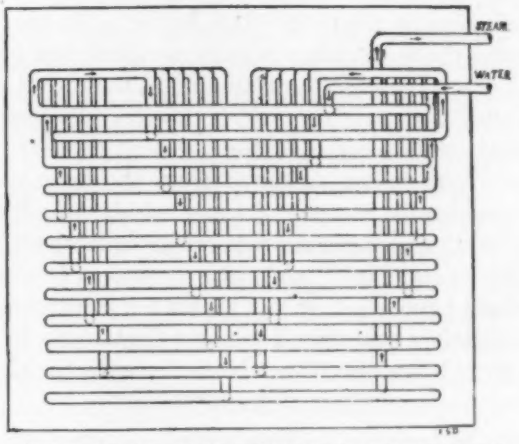


FIG. 2 DIAGRAM OF GENERATOR CIRCULATION

essential distinctive feature from every other boiler is due to the fact that the water is kept at the top and the steam at the bottom; it differs from all types of stationary boilers by the absence of a reservoir for steam. The construction of the boiler for the 18 brake horsepower engine which was used in the 1906 cars is essentially as follows, and is typical of all sizes: eleven helical coils of drawn steel tubing are joined in series and connected as shown in the diagram, Fig. 2, so as to produce a system of circulation of such a character that the water or steam, in order to pass from one coil to that next below, must rise to a level above the top coil before it can pass down again. Fig. 1 shows the external view of the connections referred to, which pass from the external circumference of the coil upward to a point above the level of the top coil and thence downward in the central

space, where it joins the coil of a lower level. Tubing having a nominal internal diameter of $\frac{3}{8}$ inch was used in the boilers of 1904–05 and 1906 and of $\frac{1}{2}$ inch in the new boiler recently built for the 1907 car.[1] The joints connecting the various coils are, it is noted, located in an accessible position. This construction makes it possible to maintain water in the upper portion of the boiler and steam in the lower. It prevents the water from descending by gravity and renders the circulation through the generator dependent upon the action of the pumps which supply the boiler with water. The general direction of circulation of the water and steam is the reverse of that of the products of combustion.

6 The White boiler has frequently been classified as a flash or semi-flash boiler; whether this classification is correct or not depends upon the definition of the term "flash boiler." In the flash boiler, as I understand the term, water is suddenly converted into steam by contact with a very hot metal surface and in the operation of such a boiler the metallic surface with which the steam is brought in contact is maintained at a much higher temperature than that of the steam. The White boiler, as noted from the description, always contains a considerable amount of water which is forced downward and over the heating surfaces at a rate proportional to the demand for steam, and under its normal mode of operation it is doubtful if the metallic surfaces have much or any higher temperature than that of the steam which they contain. The name Continuous Flow or Single Tube Boiler would, it seems to me, better describe the class to which the White boiler belongs than the term "flash."

STRENGTH

7 The construction of the boiler has been shown and described, from which it is seen that the diameter of each pressure element is small and consequently of great strength and not likely to be strained to any high percentage of its ultimate strength by any pressure which could be produced under ordinary conditions.[2] The high working pressure gives great power to the engine and explains the great success of the car in climbing high hills and in passing over unusually bad roads. A safety valve, not shown in the drawing, is attached which may be set at any desired pressure but is usually

[1]The actual dimensions of tubing used in the White boiler are as follows: E and F boiler (1905-06), internal diameter 0.372 inch, outside diameter 0.535 inch; G boiler (1907), internal diameter 0.540 inch, outside diameter 0.72 inch.

[2]The strength of the fittings at the point of leakage for the tubing I found to vary from 7000 to 18,000 lbs. per quare inch. See Appendix.

set to blow off at from 1000 to 1200 lbs. per square inch. Because of the small quantity of water and steam present in the boiler no serious damage is probable to person or property, even should the boiler tube be accidentally split or ruptured, as the effect would be simply that of allowing the steam to gradually escape without producing any disastrous results, and even this accident has been extremely rare. Considering the fact that thousands of these steam generators are in use, in the charge of men who have had practically no experience in the operation of steam plants, the results as to freedom from accident are remarkable, and indicate that the apparatus is, from the standpoint of safety, not open to criticism.

8 I have tried to get data respecting the amount of deposit of scale in the tube of the White boiler due to its continued use, but without any very great degree of success. Investigation indicates that there has been very little practical difficulty due to this deposit and the makers report only a few instances which have come to their knowledge of any trouble due to this cause. The velocity of discharge of steam through the single tube of the boiler is great and it is believed has been sufficient to remove the deposits in nearly every case. In the boiler, of which the results of the test are given later, as much as 488 lbs. of steam were produced per hour by the one-half inch tube. Without taking into account the extra volume produced by superheat, the calculated velocity approximates 400 ft. per second through the tube. Because of increased volume due to the high degree of superheat the actual velocity approximates one-third more.

9 For the actual operation of the White boiler on the motor car, water is taken from a reservoir which is supplied in great part with water condensed in an air surface condenser. The condenser is located at the front of the car and receives the exhaust from the engine which contains an appreciable amount of cylinder oil. A large proportion of this oil remains in the water tank and is discharged when convenient, but at times quite a considerable amount is forced through the boiler. So far as the makers have been able to ascertain, no injurious effects have been caused by this practice and as a consequence they have made no attempts to introduce a separator for removing this oil.

THE BURNER AND FUEL CONTROL

10 The furnace or burner which is employed with the steam generator for use on motor car is shown at *P*, Fig. 1, located beneath the boiler and adapted for the burning of gasolene vapor. The figure also shows the various means of automatic control of fuel and water

which are employed with the generator. While burners of other types adapted for other fuels than gasolene can and doubtless will be used when conditions demand it. the gasolene burner employed has proved very efficient. In the burning of gasolene a vapor must first be produced by heat or other means which must be mixed with air previous to the combustion in order to give perfect results and high efficiency; for this reason all gasolene burners are provided with means for vaporizing the gasolene before it is fed to the furnace, which usually consists of means for heating termed a *vaporizer*, as is shown at *O*, Fig. 1. The burner consists of a cast iron grate with slotted openings shown at *P* with a sheet metal chamber underneath closed except where pipes enter for admission of air as shown at *M*. In the 1905 car, the air pipes were directed radially into the chamber below the burner. In the 1906 car the air pipes direct the entering air

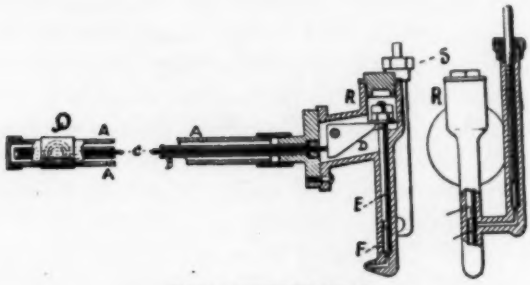


FIG. 3 THERMOSTAT

tangentially, as shown in Fig. 1. The change in the direction of the air pipes has resulted in a decided reduction of noise and an increase of capacity and efficiency of the burner. For the 1907 car the air pipe is supplied with a regulating valve. The gasolene is supplied through a pipe and flows past a valve *D* which is operated by a thermostat; it then flows into the vaporizer *O*, where it is heated; thence it flows to the center of the air pipe *M*.

11 The thermostat shown at *Y* in Fig. 1, and in detail in Fig. 3, consists of a rod inserted into the steam pipe so as to be in contact with the steam on its passage from the boiler to the engine. The expansion of this rod controls the gasolene valve at *D*, Fig. 1, and at *F*, Fig. 3. The thermostat is ordinarily adjusted so that the oil supply valve will remain open until the temperature of the steam rises to about 800° F. In order to light and relight the main burner when neces-

sary a small gasolene flame called a pilot flame, shown at *C*, Fig. 1, is kept burning constantly during the time the vehicle is in use. The valves for the hand control of the gasolene supply are shown at *L*, Fig. 1. In the operation of the burner the gasolene is discharged with considerable velocity and while in a vaporized condition into the air pipe *M*, Fig. 1, and by this operation draws in a sufficient amount of air for supporting combustion, which is mixed with the gasolene vapor and burns with a hot flame on top of the cast iron grating.

FEED WATER CONTROL

12 For the purposes of use on the motor car it is also desirable to have an automatic control of the supply of water; this is obtained in the White motor car by means of a pump which is directly connected

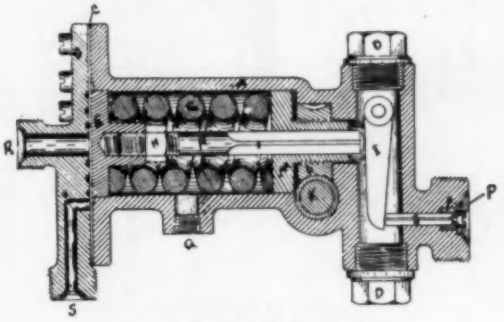


FIG. 4 WATER REGULATOR

to the engine and which may deliver water either directly into the boiler or into the source of supply, depending upon the opening of a valve controlled by the steam pressure acting against a spring, as shown in section in Fig. 4. If the pressure rises above 400 lbs. or to any desired amount, the valve *P* is opened so as to return the water through the opening *Q* to the source of supply. If, on the other hand, the pressure is below the required amount, the valve is closed by the tension of the spring and is forced by the pump into the boiler.

13 It is noted by the illustration, Fig. 1, that no water gage is supplied to the boiler and from the description of its operation it is seen that none is necessary.

14 The water circulating system is shown in Fig. 5, the generator being at the extreme right hand, the condenser at the extreme left,

with the various pumps and pipe connections intermediate. The water tank or reservoir is shown at *27A*, the two feed pumps are at *23*. These pumps are mechanically connected to the engine and take water from the reservoir *27A*, and deliver this water either into the generator or into the source of supply, depending upon whether the by-pass valves with which both deliveries are provided are open or closed. The by-pass of one pump is controlled by hand by the valve *28A*, and of the other pump by the pressure regulator which is located at *9* and has been fully described. A hand pump is provided at *17A* which may be used to fill the generator when the engine is not running. The water is taken from the lower portion of the condenser through the

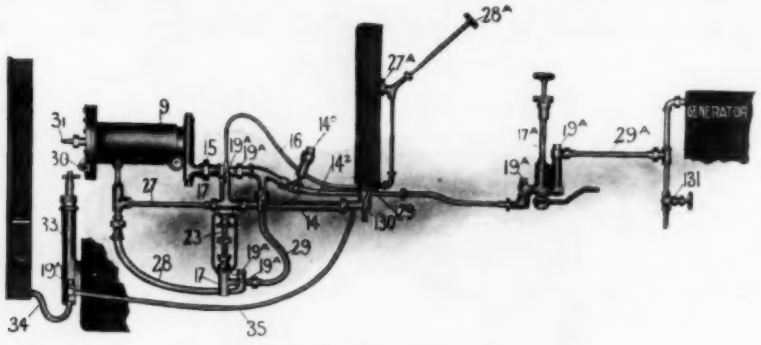


FIG. 5 WATER CIRCULATION SYSTEM

pipe *34*, by vacuum air pump *19A*, and delivered to the reservoir This pump is also kept in continuous operation by direct connection to the engine.

OPERATING CONDITIONS

15 In the operation of the plant as applied to a steam car and provided with the automatic devices as described, the fuel and water are supplied as the demand for steam requires, with scarcely any attention on the part of the operator. Thus, for instance, if the steam pressure becomes excessive, the water supply is closed off by the water regulator, Fig. 4, which immediately causes the pressure to drop. If the temperature of the steam becomes excessive, which would soon be the case if the water supply were turned off, the fuel supply is cut off by the thermostat, Fig. 3, which soon reduces the temperature to the normal amount. On the other hand, if there is an excessive amount of steam drawn off, the pressure and tempera-

ture would change in the reverse direction, which would cause the automatic devices to turn on a supply of fuel and water to meet the demand.

16 For the purposes of meeting an extraordinary demand for power which sometimes happens in ascending a long hill, an auxiliary pump already referred to is kept in constant operation by the engine, the discharge of which can be made to go either into the boiler or into the source of supply by opening or closing a valve by hand, which is located convenient to the operator. It is noted from this description

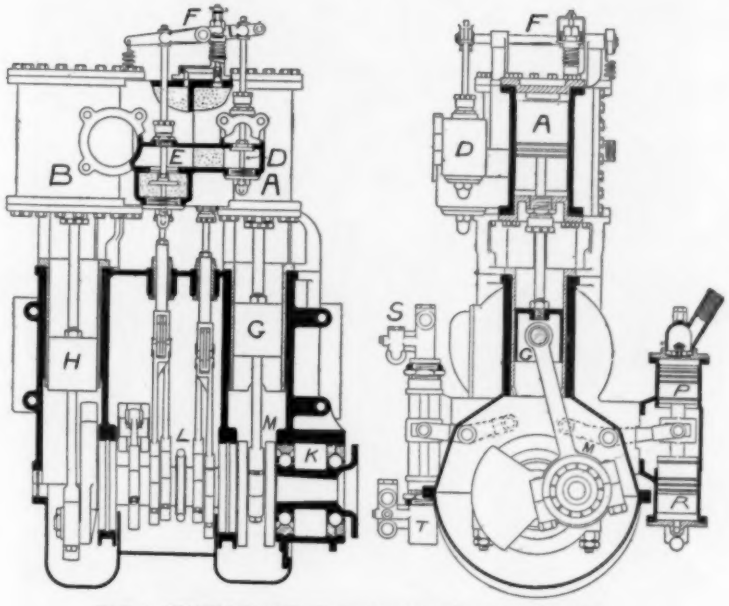


FIG. 6 SECTION AND ELEVATION OF THE ENGINE

that the operation of the White system is very different from that of the ordinary steam plant, and that the operator has little more to do than to control the motions of the engine, the steam generator providing steam when required. As used in the steam car the pressure is likely to fluctuate through wide ranges, for the reason that it will vary directly in accordance with the demand. The generator will supply high pressure steam when a large amount of power is required and steam of low pressure when but little power is needed.

THE ENGINE

17 The engine of the White steam car, as constructed for the 1907 car, is a vertical cross compound with piston valve on the high pressure and a plain slide valve on the low and which, except for its good workmanship, has no special points of merit.[1] It is provided with ball bearings throughout so as to render the mechanical friction as small as

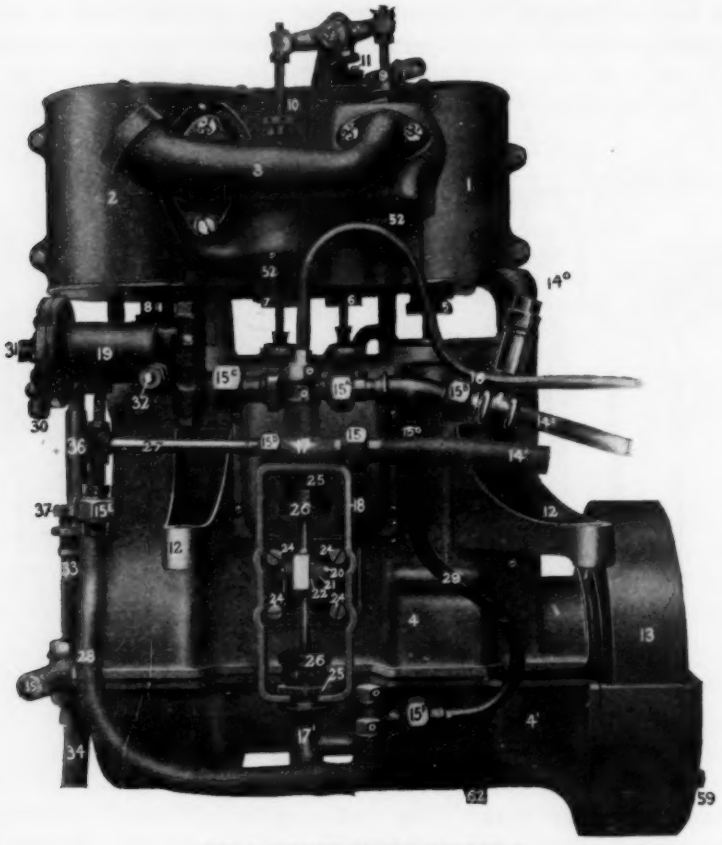


FIG. 7 FRONT VIEW OF ENGINE

possible. The cranks are set quartering so that the engine as a whole has no dead center. It is provided with a simpling device under the control of the foot of the operator which will admit high pressure steam into the low pressure cylinder when necessary either for the

[1]For the cars built 1903 to 1906, engines of similar construction but with slide valves for both cylinders were employed.

purposes of starting or for obtaining a large amount of power for use in an emergency. The valves are driven from double eccentrics through the medium of Stephenson links and are operated in essentially the same manner as those in use in the ordinary steam locomotive,

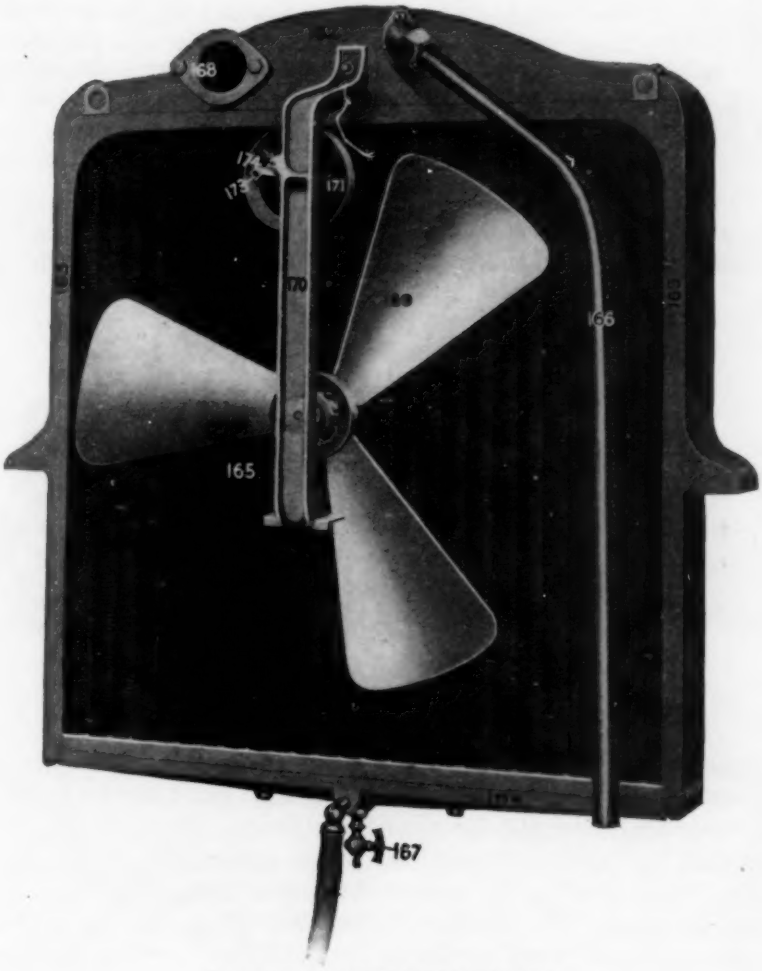


FIG. 8 BACK VIEW OF CONDENSER

i. e., the point of cut-off can be changed and the engine reversed by a movement of the link. A view partly in section of the engine is shown in Fig. 6, which will be readily understood without further explanation. The engine is directly connected to various pumps

already referred to which consist (1) of an air pump that is used to maintain an air pressure on the fuel tank for the purpose of regulating the feed of oil to the boiler, shown at *P*, (2) a vacuum air pump shown at *R*, also two boiler feed pumps shown at *I* and *S*. The one shown at *T* is provided with a by-pass controlled by the steam pressure as described, the other shown at *S*, with a by-pass controlled by hand. These pumps are simple plunger pumps with practically no mechanism to get out of order. A front perspective view of the engine is shown in Fig. 7.

THE CONDENSER

18 The steam system is provided with an air condenser which in its application to a motor car is placed at the front of the vehicle. It consists of a series of corrugated copper pipes with suitable header

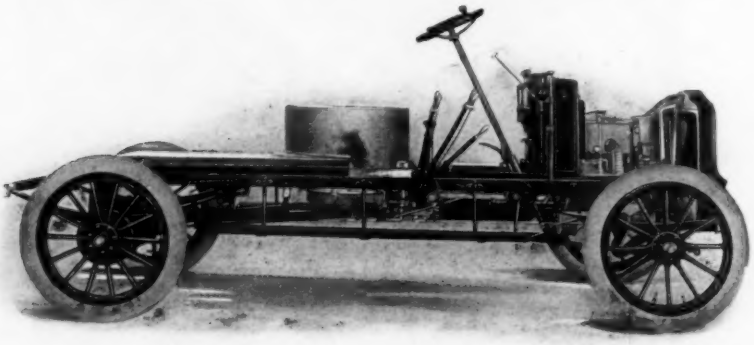


FIG. 9 THE CHASSIS

connections at top and bottom and is arranged to receive the exhaust steam into the upper header.[1] The condensed water falls by gravity to the lower header and is removed by a pump. The tubes are surrounded by air, which is circulated by the motion of the vehicle supplemented by the use of a fan located between the engine and the condensing surface. The condenser is furnished with a relief valve which opens to exhaust steam into the air in case the back pressure becomes of sensible amount. The condenser as previously applied to motor cars was not adapted to produce a sensible vacuum, its purpose being to conserve the water supply.

[1]The condenser dimensions are as follows: For E and F cars (1905-6) 74 tubes, 24.5 inches long, with a total surface of 118 sq. ft. For car (1907) of 65 tubes 27 inches long with a total surface of 136 sq. ft.

Recent improvements in the pumping system give a substantial vacuum from which a considerable increase in economy due to the vacuum is anticipated in the future. The motor car of 1907, it is expected, will maintain a vacuum of over ten inches at a speed of 20 miles per hour.

ARRANGEMENT OF PARTS

The arrangement of the power plant as applied to a motor car, is not especially pertinent to this article but being of considerable general interest is shown in the accompanying view of the chassis, Fig. 9, in relation to the supporting framework and the propelling wheels. The boiler occupies a position somewhat back of the center of the frame and discharges the products of combustion downward and to the rear; the condenser occupies a position at the extreme front, the

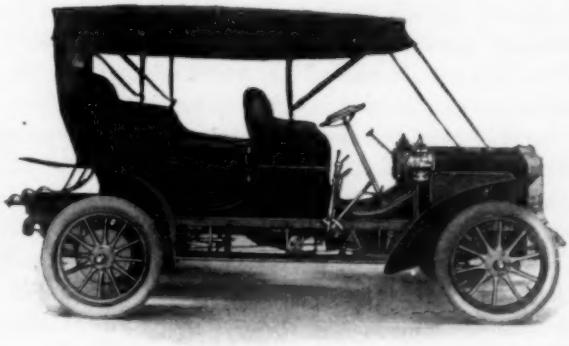


FIG. 10 THE CAR COMPLETE WITH TOURING STYLE OF BODY

engine a position just back of the condenser, and the water tank a position just in the rear of the engine. When the body of the vehicle is in position the forward seat is located directly over the boiler and an ornamental hood is placed over the engine and the space between the water tank and condenser. The throttle valve of the engine is controlled by the small hand wheel located above the steering wheel.

19 The engine is connected to the rear axle by a shaft drive which is provided with a clutch and one change gear, making it possible to operate the engine independently of the vehicle and also to vary the ratio of speed of crank shaft and rear axle. The car is provided with a double set of brakes, a steering gear controlling levers for the engine,

and a complete equipment of force feed lubricators, which need no consideration in this article.

20 In the usual operation of the car, which is shown complete in Fig. 10, the operator does little more than to steer and open or close the throttle as more or less speed is required. The automatic devices take care of the steam supply except for extraordinary conditions where an unusual amount of power is required; for such cases hand control of the water supply must be employed.

21 The engine is operated with steam superheated about 300° under usual conditions of operation, and under such conditions the steam system has shown a high economy.

TESTS OF THE WHITE STEAM PLANT

Prof. C. H. Benjamin, of the Case School of Applied Science, Cleveland, Ohio, made a very careful brake test of the steam plant of the White system of 1903 which used a 10 H. P. engine and found that when the engine was fully loaded it used only 12.6 pounds of steam per brake H. P. hour and 1.16 pounds of gasolene per H. P. hour. These results are unprecendented for small steam plants of any size and are nearly equal to the best results obtained with large triple expansion condensing engines. Some details and results of this test are given as an Appendix.

22 I conducted a test of the boiler and engine for the 1907 car from July 9 to 17, 1906, being assisted by Mr. Walter Grothe, M.E., engineer for the White Sewing Machine Company, Prof. W. N. Barnard, M.E., of Cornell University, Mr. Wm. Scaife, and Mr. George Carpenter, M.E.

23 The engine and boiler tested have essentially the same features of design as those previously used, but are somewhat larger and have increased power. The engine used in the White steam cars of 1905 and 1906 had cylinders 3 and 5 inches in diameter by $3\frac{1}{2}$ inches stroke, and was rated at 18 H. P. The one tested had cylinders 3 and 6 inches diameter by $4\frac{1}{2}$ inches stroke, and is rated by the company at 30 H. P.

24 *Dimensions of Engine* for 1907 car:

Diameter of cylinders, 3″ high pressure, 6″ low pressure.
Diameter of piston rods, $\frac{9}{16}$″ high, $\frac{9}{16}$″ low.
Clearance of engine, 17.9% high, 19.3% low.
Weight of cylinder castings with guides, 98.5 lbs.
Weight of engine frame complete, 201.5 lbs.
Weight of valves and fittings, 28.0 lbs.
Total weight, engine complete, 328 lbs.

25 BOILER: The boiler consists of nine coils of drawn tubing with a nominal internal diameter of ¼ inch, actual internal diameter of 0.53 inch, actual external diameter 0.72 inch. The external diameter of the boiler is 22 inches; its height, 11 inches. The boiler contains 243 feet in length of ½ inch tubing, and has a heating surface which is calculated as amounting to about 45.8 sq. ft.

26 The weight of the boiler without fittings is 150 lbs. The weight of casing, bolts, and all the fittings is 125 lbs. additional, making the total weight of the boiler complete as 275 lbs. The weight of burner is 40 lbs. From this it is noted that the total weight of the power system is about 643 lbs. The maximum brake horse power, as shown on the test, is about 45, hence the weight is about 14.3 lbs. per D. H. P.

27 On account of the diminutive size of the engine, its lack of governor, and the high speeds at which it is adapted to run, it was decided to make the economy test of the steam plant on the basis of delivered or brake horse power rather than that of indicated horse power. It was also believed that the use of the indicator would detract sensibly from the power and economy of the engine because of its small steam cylinders, and it was further not considered probable that indicator diagrams could be satisfactorily taken at the high speeds desirable in the operation of the engine and in the brake tests. Two series of tests were made, the first with and the second without indicators.

28 For the purpose of testing, the engine was mounted on the frame of a car in the same manner as in the completed motor car, which was, however, supported by solid posts instead of by wheels. The main shaft of the engine was connected to a plain piece of shafting about 6 feet in length and $1\frac{15}{16}$" in diameter with one end supported by a plain pedestal bearing resting on fixed foundation. An Alden Prony brake, the construction of which has been previously described before the Society (Transactions, Vol. XI, p. 959), was used to absorb and measure the power. This particular brake had an arm 26.25" which was of such length as to absorb one horse power at 100 r. p. m. for 24 lbs. supported on the brake arm. During the test the brake arm was supported horizontally by a pedestal standing on a pair of platform scales. The load was applied to the brake by water pressure obtained for the light runs from the water mains of the building and for the heavy runs from the delivery of a special pressure pump. The gross reading of the brake weighing scale which included the unbalanced brake arm and pedestal, as determined by trial, was 12 lbs. greater than the net or corrected scale reading.

29 It was not possible under the existing conditions at the time of the test to provide the necessary current of air for condensing purposes, consequently the tests had to be made with the engine running non-condensing. The weight of steam used by the engine was determined by weighing the feed water supplied to the boiler.

30 The gasolene for the test was carried in a closed tank resting on a pair of scales on which was maintained sufficient air pressure to force it into the furnace. The amount used was obtained by noting the difference in the scale readings and was taken at intervals of ten minutes during the tests. The connections from the tank for the discharge of oil and supply of air were of flexible hose arranged practically horizontal, with considerable slack and so far as I could determine by careful check readings did not affect the difference of the weights of the gasolene tank and its contents.

31 The feed water was supplied from an open tank supported on a pair of scales and connected to the feed pumps in a manner similar to that already described for the gasolene tank. The overflow from the feed pumps was returned directly to this tank so as to render any correction from this cause unnecessary. The three weighing scales were tested and found accurate. The engine was fitted with two feed water pumps, one with the by-pass regulated automatically by the thermostat, the other with the by-pass regulated by an attendant as already described.

32 Temperatures and pressures were taken of the steam, near the point of leaving the boiler, and also after it had passed the engine throttle and just before entering the steam chest; this distance was short and the connecting pipes and fittings were thoroughly lagged. Temperatures were also taken of the room, the feed water, and the boiler flue.

33 The number of revolutions per minute was determined by a calibrated tachometer and also by a motor car speedometer connected to the main shaft.

34 In making the tests a given load was applied to the brake and the brake beam kept constantly floating by an attendant. The engine speed was maintained practically constant by an operator at the throttle, who kept the needle of the speedometer uniformly at a mark on the dial corresponding to the desired speed. The speed was also determined by frequent readings of the tachometer. The steam pressure of the boiler was maintained as nearly constant as possible by another operator who regulated the water-feed by opening or closing the by-pass of the auxiliary pumps as required. It frequently took some little time to get the conditions uniform, but after

these were obtained there was no particular difficulty in maintaining it, and check runs, which were made at several times were always found in close agreement to the original ones. It will be remembered that the boiler of this car is not provided with a water gage, and as a consequence it does not have a fixed water level. From the closeness with which runs of the same brake load and speed checked at different times it is probable that for the same working conditions of temperature pressure and load, the water level remained at about the same height or at least did not sensibly vary during the run.

35 The engine was operated at speeds varying from 500 to 1200 r. p. m. in some preliminary tests, from which it was decided to make the principal series of tests at a speed of about 850 r. p. m. It was further decided to make a series of tests at constant speed and brake load, varying in length from ½ to 2 hours, instead of one long test. Several check runs were made which indicated that the errors due to this method of testing were small and not such as to seriously affect the results.

36 In presenting this paper I have given only the average results of the various runs, as it seems unnecessary to publish the figures taken in the various logs, since they differ, in most cases, very little from the average and would greatly increase the length of the paper. The results of the tests with the Alden dynamometer are given in Tables 1 to 4 and in diagrams which follow.

INDICATED HORSE POWER TESTS

37 After the brake tests at a speed of 850 r. p. m. had been completed, steam engine indicators were applied and a test was made for the purpose of ascertaining if possible the relation of brake horse power to indicated horse power. With the facilities at hand it was found impossible to get reliable diagrams at a speed greater than 475 r. p. m. For that reason it was decided to determine the relation of brake horse power to indicated horse power at a lower speed than the brake test. The results are given in Table 5.

TABLE 1

38 A little explanation is, I believe, required in order to thoroughly understand the results as given in the accompanying tables and diagrams. Table 1 gives the average results in the various brake tests of pressures, temperatures and degrees of superheat. It will be noted by reference to this table that during the various tests from 6 to 17, the boiler pressure averaged 595 lbs., the steam

chest pressure varied with the load from 152 lbs. to 427 lbs., averaging 303 lbs. The temperature of the steam near the boiler averaged 783° F., that in the steam chest 757° F. This indicates that the steam leaving the boiler was superheated nearly 300°, that entering the steam chest about 340°, and that exhausted about 28°, so that the steam in its entire passage through the engine remained in a superheated condition.

39 The temperature for the boiler steam as given in the table is that corresponding to the usual running conditions; this, as already explained, is controlled by a thermostat which is set to maintain a tem-

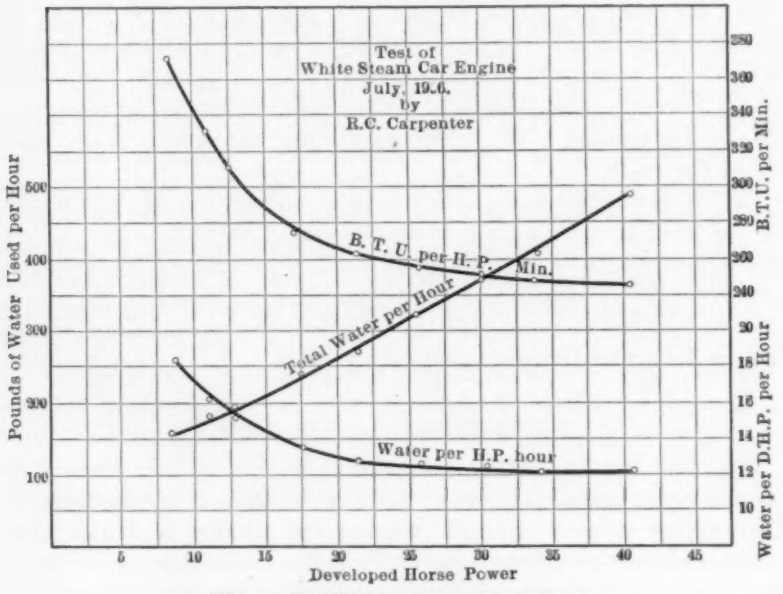
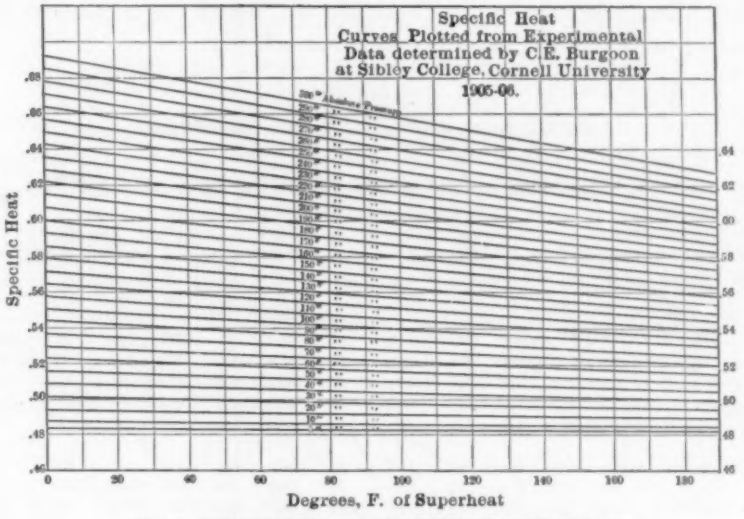


FIG. 11 ECONOMIC RESULTS OF TEST

perature of about 420° C. or 790° F. It is believed by the writer that better results are obtained in the practical operation of the car with steam at that temperature than with steam at a lower temperature. This also corresponds with certain tests which I conducted and which are in the lower part of the table, although numbered 1, 2, 3 and 4. The results of these tests differ principally from those numbered 6 to 17, in the temperature of the steam. In runs 1 to 4 the exhaust steam contained but little superheat. The amount of steam per D. H. P. per hour for these conditions averaged 13.3 lbs., whereas for the same load with the higher degree of superheat, as shown in run 6, the

average was 12.7 lbs. per D. H. P. per hour. The writer is not prepared to give any explanation of this condition, which was unexpected, but it is probably due to the entire absence of condensation at the higher degree of superheat.

40 This condition is shown by reference to the combined diagram, Fig 15, corresponding to the cards No. 6, Fig. 13, which were taken with a 60 lbs. net brake load, corresponding to 21.25 H. P. at a speed of 850 r. p. m. An expansion curve for the same weight of saturated steam is shown by the dotted line *A*—*B* which is marked "saturation curve." It is noted that the steam was slightly superheated from cut-off to release in the high, and greatly superheated in the low.



IG. 12 SPECIFIC HEAT OF SUPERHEATED STEAM

TABLE 2

41 The results given in the first seven columns of Table 2, including that for the water per D. H. P. per hour, are calculated from the data obtained in the test. The remaining portion of the table gives the heat in British thermal units above 212° F., which is received by the engine and is calculated (for the saturated part) from the heat given in the Buel steam tables[1] corresponding to the pressure in the steam chest; to this is added the heat obtained for the superheated

[1]The Buel Steam Tables are of established accuracy and were the only ones at my command which were extended to high pressures.

part, which is found by multiplying the degree of superheat, in the steam chest, by the corresponding specific heat of steam, as shown on the accompanying diagrams, Figs. 11 and 12. The total B. T. U. per pound is the sum of that contained in the saturated part and in the superheated part. From this latter amount there was calculated the B. T. U. supplied the engine above 202° per D. H. P. per minute.

42 The principal economic results of this table are shown on the diagram, Fig. 10, in relation to the total delivered horse power, from which it is noted that with the exception of the light loads the diagram representing the total weight of steam in relation to the total delivered horse power is a straight line. At light loads the line curves slightly upward and away from the straight line. The economic results at very light loads could not be obtained because of the friction of the brake even when the water pressure was off.

TABLE 1

AVERAGE RESULTS OF VARIOUS RUNS IN BRAKE TESTS

NO. OF RUN	PRESSURES		TEMPERATURES, DEGREES F.						DEG. OF SUPERHEAT			SPECIFIC HEAT*
	BOILER	STEAM CHEST	BOILER	STEAM CHEST	EXHAUST	FEED WATER	BOILER FLUE	ROOM	BOILER	STEAM CHEST	EXHAUST	
6 (2 h.)	480	275	790	763	244	87	562	81	324	349	32	.59
6 (1 h.)	480	275	790	763	244	87	562	81	324	349	32	.59
6 (1.5h.)	480	275	790	763	244	87	562	81	324	349	32	.59
7	511	152	777	730	248	74	463	83	305	364	36	.54
8	594	179	783	748	246	74	463	82	295	370	34	.54
9	525	240	779	752	246	75	465	83	307	352	34	.58
10	496	275	778	762	240	76	488	84	309	348	28	.59
11	506	180	780	743	247	76	460	84	318	365	35	.54
12	650	312	782	754	228	78	585	85	283	330	14	.59
13	625	305	778	750	244	75	580	90	284	328	32	.60
14	623	390	788	765	236	79	573	83	284	320	24	.62
15	675	427	783	767	234	75	590	83	281	317	22	.62
15a	675	427	783	767	233	75	590	83	281	317	21	.62
15b	675	350	783	767	236	75	600	83	281	331	24	.61
16	725	370	792	768	237	81	600	83	280	328	25	.61
17	608	426	783	766	232	83	540	83	293	316	20	.62
Average	595	303	783	757	239	78	543	83	298	339	28	.582
1	495	200	734	706	225	76	500	80	265	319	13	
2	540	265	734	706	212	75	490	81	256	299	0	
3	556	275	725	689	212	75	490	83	244	275	0	
4	570	250	725	698	220	81	535	84	246	293	8	

* Computed from diagram, Fig. 12, as explained.

TABLE 2

ECONOMIC RESULTS OF BRAKE TESTS

NO. OF RUN	R. P. M.	NET BRAKE LOAD, LBS	BRAKE H. P.	TOTAL LBS.		WATER PER D. H. P. PER HOUR.	B.T.U. ABOVE 212° TO ENGINE				ACTUAL EVAPORATION PER POUND GASOLENE	ACTUAL EVAPORATION PER HOUR
				WATER PER HOUR	GASOLENE PER HOUR		PER LB. OF STEAM					
							SATURATED PART	SUPERHEATED PART*	TOTAL	B. T. U. PER D. H. P. PER MINUTE		
6 (2 h.)	850	60	21.25	269.75	26.25	12.69	1027	205	1232	261	10.25	5.86
6 (1 h.)	850	60	21.25	266.5	26.25	12.54	1027	200	1232	261	10.15	5.77
6 (1.5h.)	850	60	21.25	269.0	26.33	12.66	1027	205	1232	261	10.20	5.85
7	850	60	8.5	156.0	14.81	18.35	1014	197	1211	370	10.51	3.40
8	850	31.25	11.07	180.0	18.00	16.30	1018	200	1218	371	10.00	3.92
9	875	48	17.50	234.5	22.5	13.40	1024	204	1228	275	10.40	5.10
10	850	60	21.25	269.0	25.25	12.66	1029	206	1235	262	10.65	5.86
11	850	36	12.75	195.0	18.5	15.32	1018	197	1215	309	10.55	4.25
12	850	72	25.50	320.0	31.0	12.55	1031	195	1226	256	10.31	6.90
13	850	72	25.50	322.0	31.25	12.57	1030	196	1226	258	10.30	7.02
14	850	72	25.50	320.0	31.125	12.55	1034	198	1232	257	10.30	6.98
15	850	85	30.1	370.0	31.125	12.29	1036	196	1234	252	10.42	8.07
15a	850	85	30.1	370.0	35.5	12.29	1038	196	1234	252	10.42	8.07
15b	850	85	30.1	371.5	35.5	12.30	1035	202	1237	253	10.45	8.11
16	850	96	34.0	408.8	39.25	12.05	1036	200	1236	246	10.40	8.87
17	850	115	40.7	488.0	48.0	11.96	1037	197 av.=	1224 1228	244 av.	10.15 10.34	10.7
1	700	68	19.8	265	26	13.4						
2	850	60	21.25	280	27¼	13.2	Runs 1 to 4 made with less superheat than runs 6 to 17					
3	860	60	21.25	284	27	13.3						
4	950	60	23.9	320	30.8	13.3						

* Calculated as explained in text.

NOTE—The equivalent evaporation from and at 212° F. is not computed in this text. It is approximately equal to the actual evaporation multiplied by 1.42.

EFFECT OF HEATING—FEED WATER

43 In Table 2 the heat supplied to the engine was calculated from 212°, although the actual feed water was 78° F. The actual evaporation from feed water at 78° F. to steam with pressure and temperature as shown averaged 10.34 lbs., of water for one pound of gasolene. During the tests no exhaust feed water heater was used but a heater consisting of a coil of copper pipe containing slightly less than 2 square feet of heating surface was, immediately after the close of the tests recorded in Tables 1 and 2, inserted in the exhaust in such manner that the feed water entering the boiler would be forced through it. A test was made to determine the effect of this heater,

by Mr. Scaife, who was one of my assistants during the tests which I made. This test showed that the temperature of feed water was raised by the heater from about 75 to 205° F., and that in so doing the actual evaporation per pound of gasolene was increased from 10.34 to 11.5 lbs. The results of these tests are shown in Table 3. As the cars for 1907 will be equipped with a heater containing about 3 sq. ft. of heating surface, it is believed to be fair assumption to consider that the feed water will enter the boiler at a temperature of about 212°, in which case the actual heat consumption would be substantially that shown in Table 2.

TABLE 3

TEST BY MR. SCAIFE, WITH FEED WATER HEATER

R. P. M.	NET BRAKE LOAD LBS.	BRAKE H. P.	TOTAL LBS.		WATER PER D. H. P. PER HR.	ACTUAL EVAP. PER LB. GASOLENE	TEMPERATURES, DEGREES F.			
			WATER PER HR.	GASOLENE PER HR.			FEED WATER		EXHAUST	BOILER
							A	B		
875	72	26.25	331	29	12.6	11.4	75	203.2	239	752
850	48	17.00	232	20	13.6	11.6	75	204.8	259	751
850	22	7.4	138	12	18.6	11.5	75	205.0	280	750

A, Temperature entering heater, B, leaving.

44 The above results compared with the results recorded in Table 2 show an increase in actual evaporation of 1.2 lbs. of water per pound of gasolene, due to the use of a feed water heater in the exhaust. This indicates an increase of economy of 10.4%. The heat added by the feed water heater averages 130 B. T. U. per pound. As there are about 1230 B. T. U. in each pound of steam supplied the engine; this indicates that 10.6% of the total heat as compared with the previous tests is supplied by the heater and is a fair check on the accuracy of the tests shown in Table 2.

SPECIFIC HEAT OF SUPERHEATED STEAM

45 It will be noted that in calculating the results given in Table 2 relating to the heat received by the engine, the specific heat of steam was assumed to vary and further, that it was taken as considerably greater than the value given by Regnault.

46 I will refer here briefly to the source from which these values were obtained. The laboratories at Sibley College, which are under my direction, have been working at the problem of the measurement of the specific heat of steam at intervals during the last ten years. Various methods have been tried out and abandoned and others insti-

tuted in their place. The methods employed have generally been those which would measure the heat given off in passing from a higher to a lower degree of superheat, or *vice versa*, independently from the total heat in the steam, as in that way it was hoped to avoid the errors which are always caused by measuring the total heat which is great in comparison with that used in superheating. The various methods tried were, first, measuring the heat required for superheating by a known drop in pressure, being in many respects the reverse of the method used with the throttling calorimeter for measuring the quality of steam. A second method tried was to measure the heat given off by the steam at constant pressure when being cooled from a high degree to a lower degree of superheat. The third method was the reverse of this and consisted in measuring the heat required to raise the temperature from a lower to a higher degree of superheat by the electric current. This latter method has proved the most satisfactory; although great difficulty has been experienced in getting accurate and satisfactory apparatus for producing the necessary electric current uniformly and in obtaining suitable instruments for measuring the increase in temperature.

47 For the final results we are indebted very largely to Prof. Carl C. Thomas, Mr. C. E. Burgoon, and the coöperation of the testing department of the General Electric Company in charge of Dr. W. R. Whitney. We are also indebted to Mr. M. E. Berry for the preliminary work in testing out the methods. Prof. Carl C. Thomas became interested in the determination of this result in connection with his investigation of the steam turbine and was engaged by the General Electric Company to conduct experiments for this purpose in the summer vacation of 1905. While these experiments led to no immediate results, they enabled Professor Thomas to design apparatus which the General Electric Company built which gave satisfactory and reliable results, when operated later at Sibley College by Mr. Burgoon. The temperature measurements were made first with high grade mercurial thermometers, which, however, gave irregular results. Platinum resistance thermometers were then tried which on test proved very satisfactory but which later gave results which could not be checked. Nickel-steel constantin thermal junction thermometers, which were made by Professor Shearer of the Physics Department of Cornell University, and calibrated by use of their standards, were then substituted. These proved to be reliable and gave accurate results which could be checked by experiments made later. The experiments covered a range of pressures from 0 to 220 lbs. by gage and a range of superheat for these pressures to about 400° F.

The results show an increase of the specific heat of superheated steam with increase in pressure and also a decrease in the specific heat of superheated steam with increase in the degree of superheat for constant pressure. The experiments show that for a given degree of superheat the specific heat increases directly with increase of pressure. The results are shown on the accompanying diagram, Fig. 11.

The experiments for determination of specific heat will be continued by Professor Thomas during the coming year through greater ranges of pressure and superheat, and the results will be presented in a paper before the society which Professor Thomas will prepare for a later

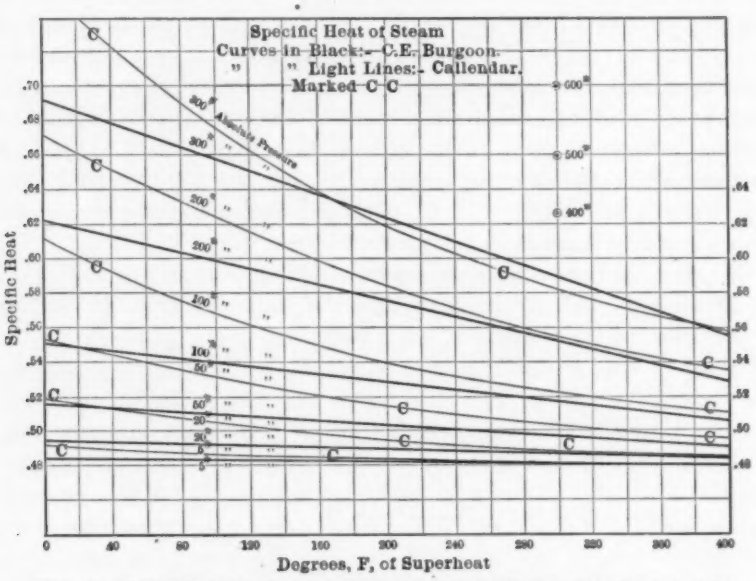


FIG. 13 COMPARISON OF SIBLEY COLLEGE RESULTS WITH THOSE OF PROFESSOR CALLENDER

meeting. The results which he has found are somewhat lower than those given by Professor Callender for low degrees of superheat, but essentially the same for high superheat. The Sibley results produced beyond the range of the experiment to high pressures and temperatures are shown in Fig. 12, compared with those by Callender.

48 It has not been proved experimentally that the specific heat continues to increase indefinitely with increase in pressure, as shown in Fig. 12. It is also true that in the tests which I made the pressures were much higher than those used in the experiment for specific heat as seen by consulting Fig. 11, but from the fact that there is no other data available for computing the heat at high pressures

and high degrees of superheat, I decided to use the results of diagram, Fig. 12, in computing the amount of heat supplied to the engine. The result of this method of computation is to charge the engine, on the average, with about 35 B.T.U. per lb. of steam more than by considering the specific heat of steam as constant, and equal to 0.48.

THE INDICATOR TESTS

49 The results of the indicator tests are shown in Table 4. These results indicate that the work lost in friction at about 460 r. p. m. averages 1.45 H. P. This includes the friction of the engine which has ball bearings throughout, the friction of one plain bearing used to support the brake shaft, and the work of operating the boiler feed pumps but not the air pumps. In the computations for the economic results per indicated horse power for tests at 850 r. p. m. I have assumed the friction of the engine to be 1.6 horse power which I believe to be nearly correct. The experiments made do not show an increase in friction with change of load and the highest and lowest results differ about ½ horse power from the mean, which no doubt can be accounted for by the difficulties of obtaining accurate diagrams under the conditions of the test.

50 The diagrams of the high pressure cylinder were taken with a 200 pound spring and those for the low pressure with a 60 pound spring. A set of indicator diagrams, reproduced by photographing the originals, taken with the link in different positions is shown in Figs. 13 and 14, from which it is noted that the cut-off varies with different positions of the link in the high pressure cylinder from 10 to 75 per cent. A combined diagram of indicator cards No. 6 is shown in Fig. 15, on which a curve showing the volume of the same weight of saturated steam is indicated by a dotted line. This line shows that the steam was slightly superheated from cut-off to release in the high pressure cylinder and considerably superheated throughout the low pressure cylinder, and that there was no shrinkage of volume in either cylinder due to condensation.

TABLE 4

RESULTS OF INDICATOR TESTS

NO.	M.E.P.		I. H. P.		TOTAL		NET BR'K LOAD	BRAKE H. P.	FRICTION H. P.	R.P.M.	STEAM CHEST PRESS.	CONDITION OF LINKS FROM CENTER	CUT-OFF HIGH %
	H	C	H.	C.									
1 H	90.0	100.5	3.30	3.65	6.95	———	—	———	———	———	———	———	———
1 L	26.6	18.3	24.0	2.68	5.08	12.03	57	10.90	1.13	365	195	2d notch	37
4 H	75.0	80.5	2.74	2.81	5.55	———	—	———	———	———	———	———	———
4 L	28.2	24.5	4.16	3.58	7.67	13.32	60	11.50	1.72	460	205	1st notch	42
6 H	94.5	92.5	3.46	3.25	6.71	———	—	———	———	———	———	———	———
6 L	16.5	20.6	2.44	3.02	5.46	12.17	57	10.91	1.26	460	195	1st notch	45
7 H	92.5	100.7	3.38	3.51	6.89	———	—	———	———	———	———	———	———
7 L	18.2	25.0	2.98	3.65	6.63	13.42	60	11.50	1.92	460	205	2d notch	37
8 H	77.5	92.5	2.84	3.25	6.09	———	—	———	———	———	———	———	———
8 L	20.4	28.2	3.02	4.12	7.14	13.23	60	11.50	1.73	465	300	3d notch	15
9 H	84.5	83.0	3.1	2.9	6.0	———	—	———	———	———	———	———	———
9 L	28.1	29.7	4.0	4.3	8.3	14.3	65	12.42	1.88	465	410	4th notch	9–11
10 H	21.8	191.3	7.95	6.7	14.65	———	—	———	———	———	———	———	———
10 L	40.3	36.7	5.95	5.35	11.3	25.95	128	24.5	1.45	460	300	full stroke	72–82
13 H	74.2	65.7	2.71	2.30	5.01	———	—	———	———	———	———	———	———
13 L	—	—	.28	.28	.56	5.57	24	4.6	.97	460	80	full stroke	78
14 H	41.7	42.8	1.53	1.50	3.03	———	—	———	———	———	———	———	———
14 L	9.5	9.12	1.41	1.33	2.74	5.77	24	4.6	1.17	460	180	2d notch	29
16 H	66.0	70.2	2.42	2.45	4.87	———	—	———	———	———	———	———	———
16 L	17.1	19.5	2.52	2.84	5.36	10.23	48	9.2	1.03	460	250	2d notch	22
17 H	126.0	120.0	4.61	4.20	8.81	———	—	———	———	———	———	———	———
17 L	21.4	22.2	3.17	3.10	6.27	15.08	72	13.80	1.28	460	185	full stroke	75
18 H	97.5	98.5	3.53	3.45	6.98	———	—	———	———	———	———	———	———
18 L	26.5	30.7	3.94	4.48	8.42	15.40	72	13.80	1.60	460	300	2d notch	22
19 H	131.0	139.0	4.80	4.86	9.66	———	—	———	———	———	———	———	———
19 L	24.2	21.7	2.58	3.17	5.75	15.41	72	13.80	1.61	460	200	full stroke	75
20 H	76.5	97.0	2.80	3.40	6.20	———	—	———	———	———	———	———	———
20 L	29.6	30.7	4.38	4.48	8.86	15.06	72	13.80	1.26	460	350	2d notch	22
21 H	149.0	145.0	5.45	5.08	10.53	———	—	———	———	———	———	———	———
21L	30.5	35.7	4.52	5.21	9.73	20.26	96	18.35	1.90	460	300	1st notch	38–42
22 H	139.0	162.0	5.08	5.67	10.75	———	—	———	———	———	———	———	———
22 L	31.1	32.2	4.60	4.70	9.30	20.05	96	18.35	1.70	460	310	1st notch	45
23 H	92.5	112.0	3.38	3.92	7.30	———	—	———	———	———	———	———	———
23 L	21.7	26.0	3.21	3.80	7.01	14.31	70	13.40	0.91	460	230	1st notch	45
24 H	77.8	79.15	2.85	2.78	5.63	———	—	———	———	———	———	———	———
24 L	21.7	20.2	3.21	2.95	6.16	11.79	52	9.95	1.84	460	165	1st notch	45
25 H	52.2	49.2	1.91	1.71	3.62	———	—	———	———	———	———	———	———
25 L	7.7	8.0	1.14	1.17	2.31	5.93	24	4.6	1.33	460	100	1st notch	45
27 H	156.5	151.0	5.73	5.28	11.01	———	—	———	———	———	———	———	———
27 L	35.2	38.0	5.24	5.65	10.89	21.90	180	20.6	1.30	460	400	1st notch	45
28 H	143.0	174.0	5.37	6.10	11.47	———	—	———	———	———	———	———	———
28 L	38.0	43.2	5.62	6.30	11.92	23.39	114	21.9	1.46	460	475	1st notch	45
								Ave.	1.45				

H = High pressure cylinder
L = Low pressure cylinder

THE FUEL

51 The fuel used in the test was gasolene supplied by the Standard Oil Company. Its specific gravity, as measured by a Beaume hydrometer, reduced to a temperature of 60° F. was 68.5, which corresponds to a specific gravity of 0.705 at 60° F. Its specific gravity as measured

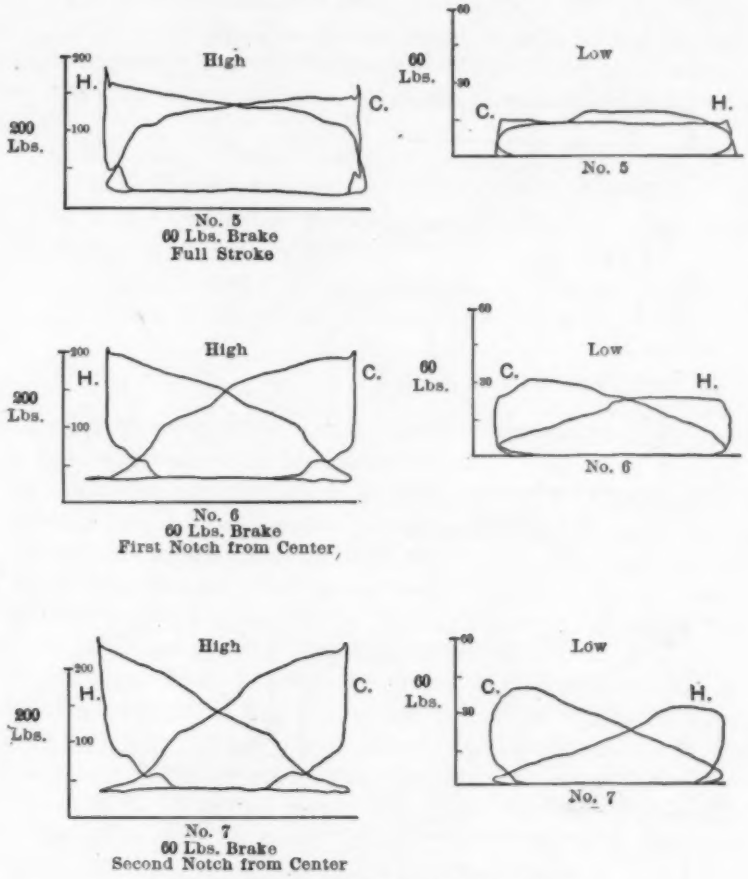


FIG. 14 SAMPLE INDICATOR DIAGRAMS

at a temperature of 75° was 0.6945, water being 1. From this measurement a gallon of gasolene at a temperature of 60° should weigh 5.877 lbs.

52 The heating value of this oil as determined by Prof. H. Diederichs, as the average of three determinations, with the Junker calorimeter, is 19,606 B. T. U. per pound for the higher value uncor-

rected for water vapor and 18,482 B. T. U. per pound for the lower value corrected for water vapor. The chemical analysis of the oil, as made by Prof. B. S. Cushman of Cornell University, showed 84.76

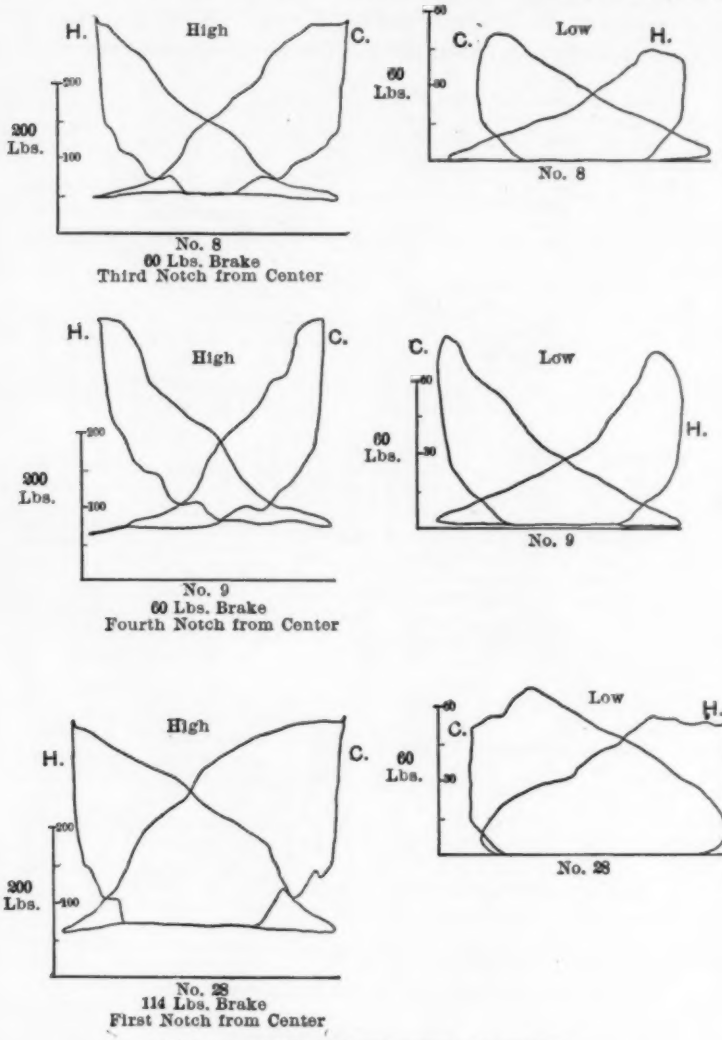


FIG. 15 SAMPLE INDICATOR DIAGRAMS

per cent C, 15.24 per cent H, from which the heating value per pound, by calculation, is 20,400 B. T. U. The lower calorimetric value is about 10% below the theoretical calculated value, a discrepancy which I am not prepared to explain at the present time, but which

I judge from consultation of a few authorities has occurred a number of times before. I consider the lower calorimetric value as more nearly representing the value of the fuel in practice than the other.

THE BOILER TEST

53 The average pressure of steam at the boiler during the various runs was 595 pounds. The average degree of superheat at the boiler was 298 degrees. The mean temperature of feed water was 78 degrees. The average evaporation was 10.34 lbs. of water for one pound of gasolene.

From this data, by consulting Buel's steam tables, we find

B. T. U. per pound of steam above 212° = 1051
B. T. U. per pound for raising feed to 212° = 144
By producing lines in Fig. 12, the
specific heat is found to be 0.69
Heat required to superheat 298° = 298 × 69 = 206

Total 1401

Equivalent evaporation from and at 212° per sq. ft. of heating surface per hour, was 13 lbs. for highest result.

54 In the above calculation the heat required for superheating is extremely approximate as the pressures in my test were about three times as high as those in the Sibley College test for specific heat of steam. In this last calculation I have obtained the specific heat as 0.69 by extending the lines in Fig. 12. This quantity gives the value of the heat in one pound of steam above 212° as 1257 B. T. U., which averages about 29 B. T. U. per pound higher than that which I calculated as supplied to the engine, and is I believe too high since the loss of heat between the points where the two observations were made was small and in my opinion must have been less than 1% or about 14 B. T. U. in this case. If the heat required for superheating were calculated by using 0.48 for the specific heat the above results would have been 1339 B. T. U. per lb. which is 62 B. T. U. or 4.4 % less than the above.

55 The heat absorbed by the steam for one pound of gasolene burned would be, in accordance with the above calculation, 14,486 B. T. U., corresponding to an equivalent evaporation from and at 212° F. of 14.9 lbs. per lb. of gasolene, and made on the supposition that the specific heat of steam is constant and equal to 0.48, it would be equal to 13,845 B. T. U. corresponding to an equivalent evaporation from and at 212° of 14.3 lbs. of water per lb. of gasolene.

56. If the heating value of the gasolene be 18,482 B. T. U. per pound, the respective boiler efficiencies for these two cases would be 78.4% and 75.0%. If the heating value be assumed at 20,400 B. T. U. per pound, the respective efficiencies become 71.2 and 67.3%.

THE EFFICIENCY OF THE ENTIRE PLANT

57. The engine developed a horse power on the brake at its highest load during the various tests with a consumption of 11.96 lbs. of feed

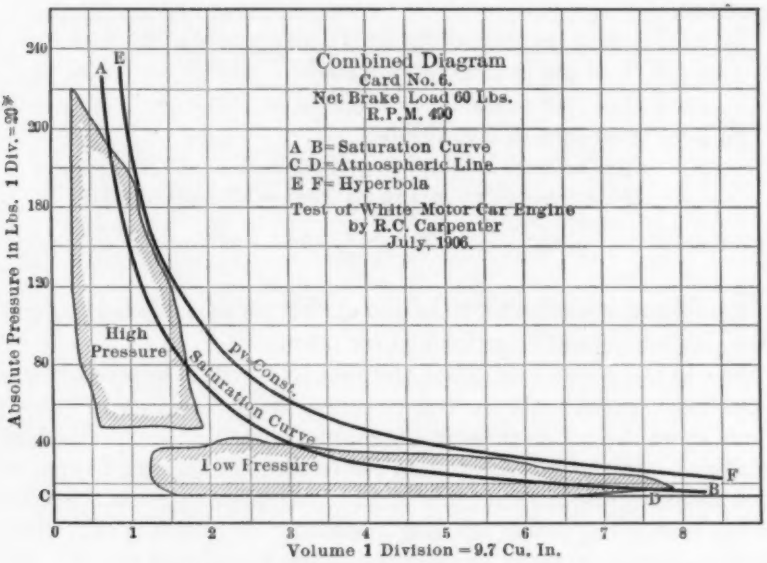


FIG. 16 COMBINED INDICATOR DIAGRAMS

water per hour. The evaporation under actual running conditions with the feed water heater in operation was 11.5 lbs. of water for one of gasolene. This would show that 1.04 lbs. of gasolene would be used under best conditions per developed horse power.

58 If the engine friction be considered as 1.6 horse power, the water per I. H. P. per hour would be as calculated under best conditions, 11.54 lbs. and the gasolene per I. H. P. per hour, 1.004, which is practically one pound of gasolene per I. H. P. per hour.

59 If the gasolene has a heating value of 18,482 B. T. U. per pound, we find a heat efficiency for the whole plant on the basis of total heat supplied, compared with that converted into useful work on the brake, of 13.25%, and compared with that indicated of 13.35%. If

the heating value for gasolene be 20,400 B. T. U. per pound the per cent of efficiency for these two cases becomes respectively 12.1 and 12.45%.

60 The above calculations are made to cover the extreme results of the heating values of gasolene, in order to make the results accord with either method of calculation.

SUMMARY OF TESTS MADE BY PROF. C. H. BENJAMIN

61 The test made of the White steam system by Prof. C. H. Benjamin in 1903 has already been referred to, and a summary of the results is given here for comparison with the tests which I made.

62 The engine tested by Professor Benjamin was of the vertical cross compound type with high pressure cylinder 3 inches in diameter, low pressure cylinder 5 inches in diameter, and with a stroke of 3½ inches. Its general construction was in many respects similar to the 1907 engine which has been fully described; it was not, however, provided with ball bearings. The test was made by essentially the same method as described in the paper. During the test the engine was operated at 675 r. p. m., the friction horse power determined in Professor Benjamin's test was approximately 2 which, however, included that of an extra countershaft which was not required in my test.

63 Professor Benjamin's tests show a consumption of water per brake horse power per hour varying from 12.6 to 19.9 and per indicated horse power per hour an amount varying from 10.8 to 14 lbs.

64 Respecting these results Professor Benjamin states: "This is a remarkable showing for an engine of this size. When the fact is considered that ordinary simple engines use from 25 to 35 lbs. per indicated horse power per hour, and that 12 pounds is considered good performance for triple expansion condensing engines the remarkable nature of this performance is better understood."

65 The following gives the principal results in tabular form of the test made by Professor Benjamin:

PRINCIPAL RESULTS—TEST OF WHITE ENGINE OF 1903

By Prof. C. H. Benjamin

BOILER PRESSURE	TEMP. F.° FEED	TEMP. STEAM (BOILER)	TEMP. STEAM (ENGINE)	SUPERHEAT (BOILER)	SUPERHEAT (ENGINE)	TEMP. (EXHAUST)	WEIGHT GASOLENE PER 30 M	WEIGHT WATER PER 30 M.	ACTUAL EVAP. PER SQ. FT. H. S. PER HOUR	ACTUAL WATER PER H. P. HOUR	GASOLENE PER H. P. HOUR	EQUIV. STEAM PER H. P. HOUR AT 212°	BRAKE H. P.	CUT-OFF
263	51	763	695	353	285	288	6.6	72	3.92	12.6	1.16	16.3	11.4	.75
250	47	779	725	373	319	289	6.5	68	3.71	14.9	1.42	19.7	9.15	.75
274	47	786	739	369	325	360	6.0	68.2	3.72	19.7	1.74	26.3	6.92	open
244	47	772	718	368	314	339	5.7	60.5	3.30	17.5	1.65	23.1	6.92	.75
356	48	782	735	345	298	298	5.3	54.5	2.96	15.8	1.53	20.4	6.92	.50
388	46	793	726	347	280	293	4.6	46.5	2.53	19.9	1.97	25.9	4.66	.50
483	47	796	711	329	244	344	3.0	29.7	1.63	24.8	2.5	31.8	2.4	.50
380	47	737	632	294	189	354	2.0	15.7	0.76	—	—	—	0	.50

SAW-TOOTH ROOFS FOR FACTORIES

By KNIGHT C. RICHMOND, PROVIDENCE, R. I.
Junior Member of the Society

1 By a saw-tooth, as applied to roofs, we generally mean a form of skylight, a cross-section of which approximates a 30° x 60° draughtsman's triangle with the hypothenuse horizontal, the right angle at the top, the glass in the short leg only, and the long leg forming the roof proper. Such saw-teeth can be used singly of any convenient length, in successive rows, or in any desired combination to fit particular conditions. The ridges at the peaks of the saw-teeth may run across the building, or lengthwise of the building, or diagonally, as best suits the requirements of a given case. The object of saw-tooth lights is to obtain overhead light, and in most cases the windows of the saw-teeth are placed facing directly or nearly north, and the angle of the window with the vertical made so small that direct sunlight cannot enter.

2 The saw-tooth form for factory lighting, was first developed, I believe, in England, whence it spread to the continent of Europe, and sometime in the seventies began to be used in the textile mills of the Philadelphia district. Possibly some of the Members can tell of the first application of saw-teeth to factory roofs in this country.

3 At present this form of roof lighting has found wide application in many kinds of factory service. Wherever the space to be lighted is of large floor area, and the occupancy such as to require only comparatively low head room, say from 11 to 20 feet, and where it is desirable to avoid direct sunlight, while still obtaining an abundance of almost perfectly diffused light, there seems to be a use for saw-tooth roofs. Such conditions occur in textile mills, especially in the weaving rooms; in dye houses where light is necessary for the careful matching of shades; in drafting rooms, in many classes of machine shops, and in a great variety of light manufacturing.

[1]To be presented at the New York meeting (December, 1906) of The American Society of Mechanical Engineers, and to form part of Volume 28 of the Transactions.

4 In heavy machine works, where rooms are of height sufficient to accommodate traveling cranes, and buildings are relatively narrow, say not over a hundred or a hundred and twenty-five feet wide, and where a large amount of high light can be provided by side windows, and the direct light from roof skylights glazed with some form of diffusive glass or translucent fabric, there seems to be little use or argument for saw-tooth roofs.

5 The purpose of the saw-tooth form of lighting being, in most cases, to provide direct skylight in large quantity, and at the same time to avoid direct sunlight as far as possible, it follows that north of the tropics the saw-tooth windows must face nearly north, and the angle of the sash with the vertical be made dependent on the latitude of the location, the angle increasing the further we go north. In the latitude of New York, about 41°, this would mean an angle of only 17° to 18°, to keep out the sun in the longest summer days, were it not for the small projecting cornice above the window, and the internal stool or gutter at the bottom. These projections enable us to make the angle of the glass with the vertical greater than we otherwise could do, and with the form of setting and trimming frequently adopted, angles from 25° to 30° have proved satisfactory in practice in New York and New England. The angle of the glass with the vertical could be made much greater, and still keep out direct sunlight, if the cornice above the windows were extended, or a screen or barrier run along the crests of the saw-teeth. A very interesting modification of saw-tooth lighting on the above line has been made by Mr. Willard T. Hatch, a Member of the Society, in the treatment of foundry roofs, where he has placed the glass skylights on one side only of the successive ridges of the roof, and used the continuous ventilating monitors at the peak of the ridges, as a screen to keep direct sunlight off the glass, thus making the angle of the glass with the vertical much greater than would otherwise be possible, at the same time getting the benefit of the brighter light of the upper sky in much greater degree than would be the case were the same area of glass placed more nearly vertical.

6 Where the angle of the glass with the vertical is made greater than a theoretical consideration of the latitude permits, for the reasons above noted, and the windows face the north, it follows that at seasons when the sun rises and sets north of the equator, that there will be a little direct sunlight on the windows for a little while after 6 a. m., and also for a little while before 6 p. m., solar time being used in the reckoning. Mill hours in the North usually begin about 6.30 a. m. and end about 6.00 to 6.15 p. m., or, in other words, the help work a

greater number of hours after mid-day than they do before it, and where the compass points of the building are not already determined by other considerations, we can avoid in a large measure the direct light of the late afternoon sun in summer by placing the building so that the saw-teeth will face from 5° to 15° east of north, and still not have trouble from direct sunlight before bell-time in the morning.

7 The framing of a saw-tooth roof may be of wood, steel or reënforced concrete, or any suitable combination of the above. No unusual problems are presented other than adapting them to the case in hand, making the obstruction to light as small as practicable. The plane of such roofs is generally nearly level, or only slightly pitched, and the saw-tooth form makes the lodgment of great quantities of snow possible, for which reasons the framing should be of ample stiffness to prevent sagging and the holding of water in puddles on the roof surface. The weight of piping, shafting, motors, machinery, or equipment, to be carried, must be considered in each individual case, and provision should be made for the same in the design.

8 In textile mills the roof itself is generally made of matched or splined plank about three inches thick, in accordance with the practice of slow-burning "Mill Construction," and the framing of yellow pine lumber in very simple trussed forms, with members of ample section to meet the slow burning standard. Where steel framing is used, as is common in machine shops, the simplest forms consistent with economy of metal are the best. The writer does not know of a saw-tooth with reënforced concrete framing, but believes it readily adaptable where fire-proof construction is very desirable, as, for instance, in large drafting rooms. Reënforced concrete is reported as successfully used for roofing, and seems to combine great advantages, if lined with proper insulating material to prevent condensation.

9 Any form of roof covering which successfully withstands the attacks of heat, cold, wind, rain, snow, and ice, after it is applied to the steep pitch of the back of the saw-tooth, is available. "Gravel" roofs laid with crushed slag in asphalt, have successfully held on slopes as steep as six inches to the foot in the New England climate, and some of the prepared felted roofings have proved satisfactory. Good materials and extreme care in applying seem to be the secrets of good service on saw-tooth roofs as on others.

10 The usual arrangement of saw-teeth in roofs of large rooms, namely, successive rows of windows, facing north, with the backs of the saw-teeth, which form the roof proper, sloping down to the valley at the bottom of the next row of windows, makes the exposure to cold particularly severe, and due allowance must be made for this

in the heating scheme. In textile mills where a relative humidity of 75 to 80, with temperatures about 80° F., is desirable for manufacturing, the tendency to roof and window condensation in cold weather is very large and the usual plank roof is not of itself sufficient to prevent such condensation. Sometimes the planking has been furred and sheathed, dependence being placed on the air space between plank and sheathing to act as a non-conductor of heat, but the writer's experience is that such sheathing is only partially effective, and that condensation is constantly taking place in very cold weather between the plank and sheathing, which works through the joints in the sheathing making drips and stains, and helps to rot both plank and sheathing. Should a layer of good insulating material be placed between plank and sheathing, the result I think would warrant the expense. I have used a double layer of Cabot's sheathing quilt, made of dried sea-weed, between the plank and sheathing of a flat roof of a factory office, with satisfactory results, and at small expense, and the same treatment seems applicable to saw-tooth roofs. Any treatment which increases the insulating power of the roof against the passsage of heat, and at the same time does not increase the fire hazard, or cause dirt after it is put in, will increase the comfort of the help in both cold and hot weather, with a lessened expense for heating in cold weather.

11 The portion of the front of the saw-tooth directly below the window stools, should be at least as thick and as well insulated as the backs of the saw-teeth, as this part of the roof forms one side of the valley between the lines of saw-teeth, and being out of the line of direct sunlight in the winter, snow will remain there longer than on other parts of the roof, with consequent chilling of the roof.

12 Frequently the sash are double glazed with an air space about three-quarters of an inch between the lights, and this is of undoubted value in keeping heat in the building in cold weather. One glazing is often done with "factory ribbed" glass, the ribs running lengthwise of the window, and the ribbed side placed toward the air space between the lights. The ribbed glass assists in the diffusion of the light, which is sometimes strong, even with a north exposure, due to reflection from clouds. In all cases where delicate shades are to be matched, insistence should be placed on having all the glazing done with white glass to avoid the green tint of the light coming from the ordinary glass, which shows green when looked at edgewise. In spite of double glazing, there will generally be some window condensation which must be taken care of by internal gutters at the bottom of the sash. Such gutters may drain into a system of internal piping,

or have an outlet under the bottom of the sash itself, draining the condensation out onto the roof, the outlet being so arranged that the warmth of the building will keep it open against freezing.

13 The heating of rooms with saw-tooth roofs presents no special difficulties, if the amount of glass and severe exposure are duly considered. Where direct radiation is used, three or four lines of inch and a quarter pipes, heated with steam, or hot water under forced circulation, and placed near the bottom of the fronts of the saw-teeth, and running their entire length, give very satisfactory heating, and prevent in large degree the troublesome roof and window condensation, by applying heat at the points where it is most needed. If there is no moving machinery in the room to keep the air in motion, wall coils near the floor may also be needed, as for instance in drafting rooms. If the saw-teeth do not extend to the outside walls, and flat places are left in the roof near the walls, direct radiation should be provided for preventing condensation at such places. Some very large rooms, containing about 200,000 square feet of floor surface, have been successfully heated, and very freely ventilated, by drawing air from the basement through steam heated coils, and delivering it at various places in the rooms by means of draft fans and ducts. The chief objection to this method is in the amount of steam necessary for heating, which is undoubtedly greater than for equivalent heating by direct radiation properly applied. Unfortunately I have been unable to get quantitative measurements of the amount of coal needed by the two systems. The fan circulation of air proves its value in hot weather in weaving rooms, according to the reports of those who use it, by affording increased comfort to the help, so that they work with greater efficiency. At such times the fans simply deliver the cooler basement air in large quantity to the working room.

14 The ventilation and cooling in hot weather, of large rooms with saw-tooth roofs, where the height under the framing runs from about eleven to sixteen feet, is a question always needing attention in the design. Such roofs have been built where the sash in the saw-teeth were all fixed sash, and the side walls contained no windows, or only small ones, and ventilation was dependent on small windows in the ends of the saw-teeth, aided by such ventilation as came from a few entrances, and the movement of air through the belt holes in the floor. In hot and muggy weather such rooms became extremely uncomfortable, and some owners have since installed steamboat, or other, ventilators at the ridges of the saw-teeth with satisfactory results. Others have changed some of the fixed sash to pivoted or hinged sash, the chief objection to which is the difficulty of making them tight in driv-

ing storms, on account of their inclined position. In one case noted some of the fixed sash were simply removed, as there was little danger of water damaging the work in the room below. I think the common two-casement window can be readily adapted to saw-tooth skylights by extending the outer casings over the sash rims, and arranging for the upper half only to slide, and by balancing the upper half by spring lifts instead of weights. Revolving "steamboat" ventilators, with dampers in the flues, are easily placed at the ridges of the saw-teeth, and give good service, when made of material which withstands corrosion. The number and size of such ventilators depends entirely on the special conditions in each particular case, and is hardly subject to general rules. Where windows have been placed in the side walls of saw-tooth lighted rooms, it is the writer's experience that these wall windows are generally found open in hot weather, which would seem to justify their existence. As fans are efficient as ventilators in both hot and cold weather, and as direct radiation is more economical for factory heating than indirect acting through a fan circulation, the best service would seem to be given by installing fan capacity sufficient for adequate ventilation only, tempering the air in cold weather, and placing the main reliance for heating on direct radiation.

15 The flashing and draining of saw-tooth roofs have given trouble at times. The great length of flashing in the valleys between the saw-teeth gives opportunity for much expansion and contraction and the piling up of snow in the valleys, with a relatively warm roof melting it on the underside, gives a chance for water to work up over the lower flashing, unless the same is of ample height and very carefully put in, and provision made for promptly carrying off the water from the melting snow. Where the saw-teeth run across the building, the roof is often pitched from the center ridge to both sides on a slope of a quarter to a half an inch per foot, and the water carried off in conductors which run down on the inside or the outside of the outside walls. Outside conductors have proved very undesirable in New England on account of the water freezing as soon as it has passed from the warm surface of the roof to the cold outside conductor. The result is a great mass of ice, and generally a broken conductor. It is altogether desirable, in climates where water freezes in the winter, to run the conductors down on the inner face of the side walls and to make both the strainers and conductors of ample capacity to carry off any probable amount of rain or melted snow.

16 Where the ridges of the saw-teeth run with the length of the building, water can be most conveniently removed from the valleys

by conductors placed at intervals of 40 to 60 feet apart in the valleys. Experience in New England seems to show that a three inch conductor so placed is amply sufficient to take care of 1000 to 1200 square feet of roof surface, providing the conductor has a free downward run of 12 or 15 feet. A slight pitch of the bottom of the valley toward the conductor opening in the roof, is easily effected by furring up the roof under the roof covering. In a roof recently built from the writer's design, a pitch of three inches in 20 feet proved amply sufficient to remove all the water from the bottoms of the valleys. The conductors after coming through the roof can be connected into a larger pipe near the roof, or be carried down through the room, and be disposed of in the basement. The strainer on the roof often fits into a roof thimble made tight with the roof covering, and the thimble runs down into the conductor pipe proper. The connection of the roof thimble with the top of the conductor is frequently a slip joint, made by slipping the thimble some twelve inches down into the conductor, and when the pipe connecting the conductors is near the ceiling, and only slightly pitched, there is danger in very heavy rains of its filling, and of the water backing up and overflowing between the roof thimble and the top of the conductor, unless the connecting pipe is made of very ample proportions. I think it is better to carry the conductors down to and through the floor and gain the effect of the head in the vertical pipe to rapidly discharge the water. The conductors themselves should be of stout construction, where they come down through the room, and ordinary wrought iron pipe has been found a satisfactory material. Cast iron soil pipe is liable to be broken, and the sheet metal conductors of commerce are sure to be bent and dented in factory service. When columns are of iron pipe, or of hollow cast iron, they can be readily utilized for roof conductors, and where the columns are not used for conductors, the conductors can be run in line with the columns without wasting valuable floor space. The writer's feeling is that it would generally be better to make the plane of the roof level, even when the saw-teeth run across the building. This brings the girders carrying the saw-teeth all on a level, and the room is of uniform height under the girders, which in some measure simplifies the installation of machinery and shafting. Where there is no overhead shafting, a difference of a few feet of the height of the roof at different points may make no difference in the value of the room as working space, and it is cheaper to drain the roof by a few large conductors at the ends of the valleys at the outside walls, than by a system of small conductors at intervals, as described.

17 Even with the amount of light furnished by a properly proportioned saw-tooth roof, a very large gain is made by a thorough whitening of all interior surfaces, and this should never be omitted where light is of value, and where there is any probability of the paint remaining white after it is applied.

18 The fire hazard of saw-tooth construction presents no difficulties from the insurance point of view, as far as I can ascertain, and no discrimination in rates is made against such construction. While the serrated form in some measure prevents the free play of hose streams against the ceiling, the same form also tends to prevent the free advance of fire in a direction across the ridges of the saw-teeth, and the great number of roof windows make it possible to attack the fire at any point by hose streams from above. The very large area of many rooms with saw-tooth roofs, rooms with 100,000 to 200,000 or more square feet of floor without partitions offer the objections, from the insurance point of view, made to all such large spaces, but the installation of automatic sprinklers with ample water supply, in accordance with the insurance regulations, overcomes such objections as far as they affect rates. In other words, the large saw-tooth lighted room is insured at the same rate as the remainder of the factory, providing the occupancy is the same. At this point it may be noted, that while the simplest forms of framing with a few very substantial members are always desirable when building in accordance with the slow burning requirements of "Mill Construction," nevertheless the growing use and ready adaptability of structural steel framing, and the rising price of lumber, with the difficulty of obtaining large sizes promptly, which almost compels the substitution of trussed forms and smaller sticks, makes the consideration of such forms almost a necessity, and I do not find that they are prejudicial to insurance rates, providing always the sizes are kept reasonably large, say not less than 6″ x 8″ in members under compression or acting as beams, and providing also that there are sufficient sprinklers and water to reach all parts of the framing exposed to fire. While a few years ago, yellow pine was much cheaper than structural steel, strength for strength, today the difference in cost is so small between sizes of yellow pine of say 10″ x 16″ and up, and a steel beam of equal strength, that it is sometimes economical to use steel in place of lumber, and saw-tooth roofs are successfully built with a combination of both materials in the framing.

19 The amount and diffusion of light can be made almost perfect for the most exacting requirements, and this is the preëminent advan-

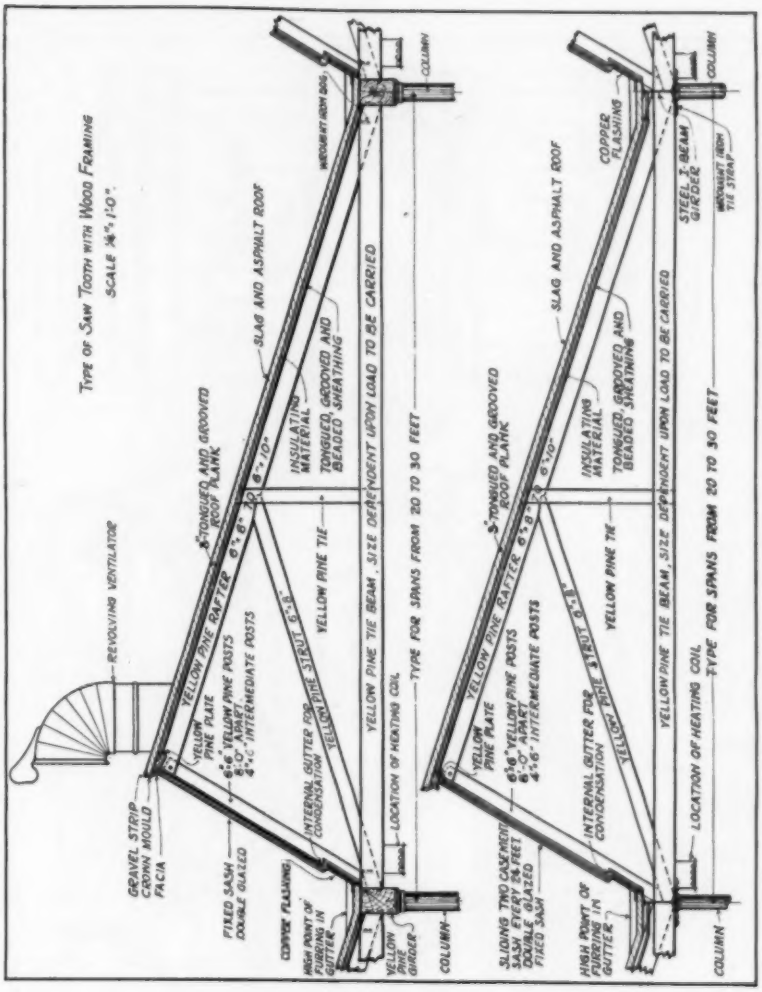


FIG. 1 TYPES OF WOOD FRAMED SAW-TEETH FOR SPANS FROM 20 TO 30 FEET

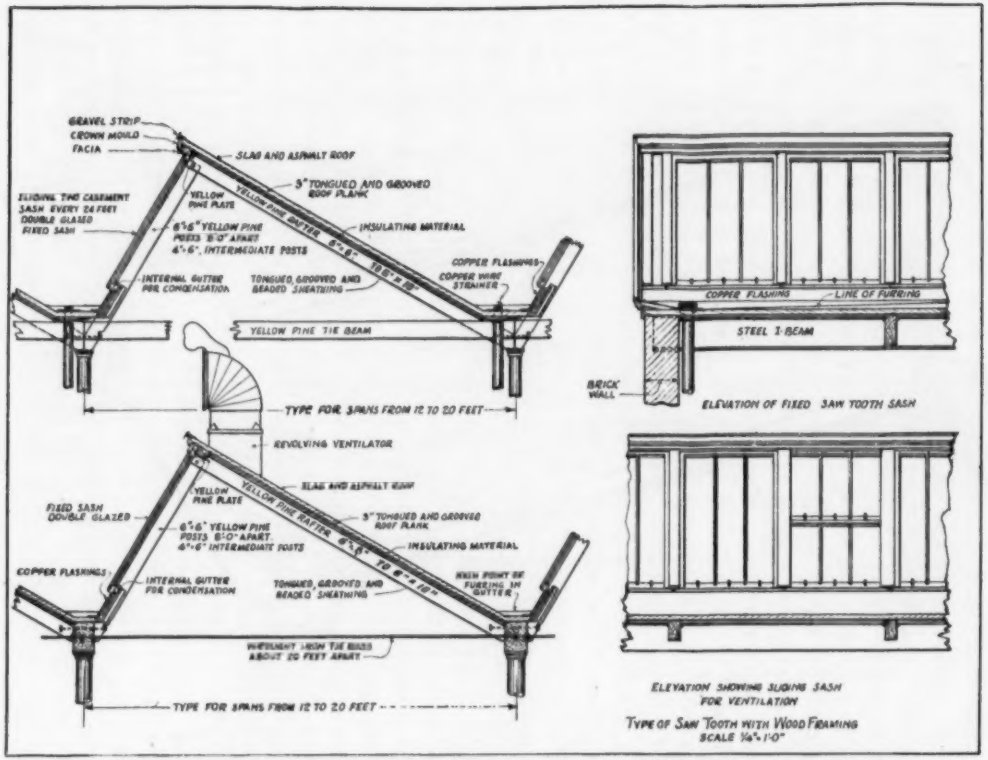

GRAVEL STRIP
CROWN MOULD
FACIA
SLAG AND ASPHALT ROOF
3" TONGUED AND GROOVED ROOF PLANK
YELLOW PINE PLATE
YELLOW PINE GUTTER 6"×8"
INSULATING MATERIAL
SLIDING TWO CASEMENT SASH EVERY 24 FEET DOUBLE GLAZED FIXED SASH
6"×6" YELLOW PINE POSTS 8'-0" APART 4"×6" INTERMEDIATE POSTS
INTERNAL GUTTER FOR CONDENSATION
TONGUED, GROOVED AND BEADED SHEATHING
COPPER FLASHING
COPPER WIRE STRAINER
YELLOW PINE TIE BEAM
TYPE FOR SPANS FROM 12 TO 20 FEET
REVOLVING VENTILATOR
SLAG AND ASPHALT ROOF
YELLOW PINE PLATE
YELLOW PINE RAFTER 6"×8" TO 8"×10"
3" TONGUED AND GROOVED ROOF PLANK
FIXED SASH DOUBLE GLAZED
6"×6" YELLOW PINE POSTS 8'-0" APART. 4"×6" INTERMEDIATE POSTS
INSULATING MATERIAL
COPPER FLASHING
INTERNAL GUTTER FOR CONDENSATION
TONGUED, GROOVED AND BEADED SHEATHING
KNEE POINT OF FURRING IN GUTTER
WHITEWOOD HIGH TIE BEAMS ABOUT 20 FEET APART
TYPE FOR SPANS FROM 12 TO 20 FEET
COPPER FLASHING
LINE OF FURRING
STEEL I-BEAM
BRICK WALL
ELEVATION OF FIXED SAW TOOTH SASH
ELEVATION SHOWING SLIDING SASH FOR VENTILATION
TYPE OF SAW TOOTH WITH WOOD FRAMING
SCALE 1/4"=1'-0"

FIG. 2 TYPES OF WOOD FRAMED SAW-TEETH FOR SPANS FROM 12 TO 20 FEET

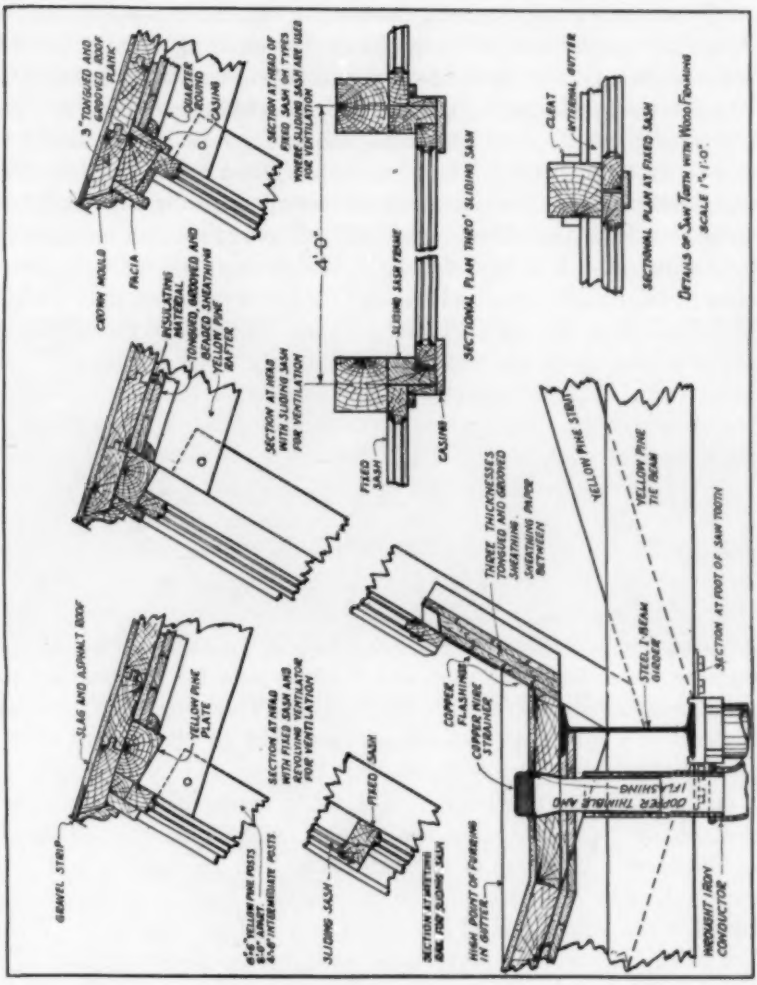


FIG. 3 TYPICAL DETAILS OF WOOD FRAMED SAW-TEETH

tage of saw-tooth lighting. By no means a small economy in the use of saw-tooth roofs is the saving in time during which artificial light is needed, as compared with side-lighted rooms in factories of usual proportions. One textile mill in which a saw-tooth lighted building of very large area is near a several storied building about ninety feet wide, the same processes being followed in both buildings, reports that lights are lit an hour earlier in the storied building than in the saw-tooth building. As the lighting frequently runs up into the hundreds of horse-power, the saving is material. It is frequently reported that a greater production of the same class of goods is obtained from saw-tooth lighted rooms, than from side-lighted rooms, with identical machinery running at the same speed in each, and it is somewhat hard to believe that the difference exists. The explanation seems to be primarily in the almost perfect light, and from the fact that a better class of help is attracted and retained for the very reason that the light and working conditions are better. In one case at least the advantage of the saw-tooth lighted building is distinctly measured by the lower piece price paid for weavers in the saw-tooth building as against the piece price paid weavers on the same class of work in the neighboring side-lighted building. The difference is stated to be ten per cent.

20 The cost is undoubtedly greater for a saw-tooth roof, than for a flat or other plane roof. The actual amount of roof is almost as great ordinarily in the saw-tooth form as in the plane form, and may be more, and in addition there is more framing, all the windows with their trimming, all the flashing below the windows and in the internal gutters, a large amount of painting, frequently a larger cost for conducting water from the roof, and a larger cost for the heating and sprinkling, as compared with plane roofs. These items may increase the cost of a saw-tooth roof from 40 per cent to 60 per cent over a plane flat roof without skylights, but this can hardly be considered a fair measure, as to obtain results fairly comparable with properly designed saw-tooth lighting, the engineer must consider the whole cost of side lighted buildings of sufficient height in the stories and sufficiently limited in width to give satisfactory light, and should also consider the whole cost of the saw-tooth lighted building. Where the work or process requires large amounts of nearly perfect light, or where the work is bettered or done at less cost by having it, the final balance of advantage seems to incline strongly toward the saw-tooth form, as is evidenced by the great increase in recent years in the use of saw-tooth lighted buildings. This is very noticeable in buildings erected for fine and fancy weaving. Many of these have been designed by Members of the Society who make a spec-

ialty of textile mills, and who early recognized the advantages of this type, and now such buildings may almost be considered as the standard form for this class of work, with the saw-tooth trusses made in the simplest forms.

21 The proper proportioning of the saw-tooth light is important to obtain the best results without wasting money in their erection. Some saw-tooth roofs have been designed with the span of the saw-tooth very short relative to the height, thus making the backs of the saw-teeth very steep, and the valleys sharp and narrow. The result seems to be some loss of light, on account of the obstruction formed by the backs of the saw-teeth themselves, and there is an unnecessary expense for glass and flashings, as fewer saw-teeth with longer spans or the same number of saw-teeth with shorter windows would give all the light needed. The photograph below shows a roof

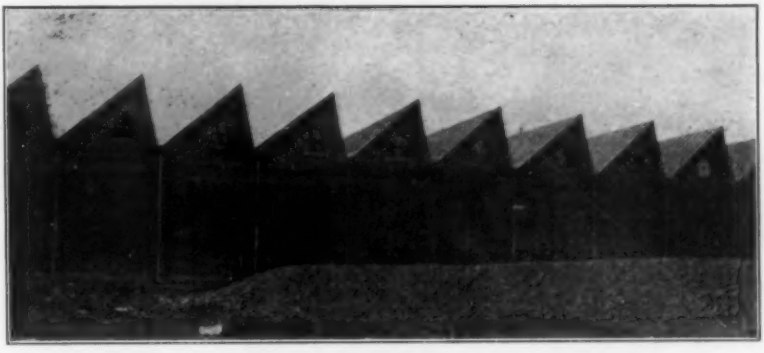


FIG 4 NEW ENGLAND WEAVING MILL. SAW-TEETH CRITICISED AS TOO HIGH FOR THE SPAN

against which this criticism is made. The experience of the writer after an examination of the lighting effect in a very considerable number of saw-tooth lighted rooms, designed by different engineers, is that to obtain the best results, there should be no intervals between the saw-teeth. A flat place on the roof generally means a shadow, even if slight, or perhaps only a less brightly lighted area, and makes a break in the otherwise almost perfect diffusion of the light. By the same reasoning the obstruction caused by the necessary space and flashings below the windows and by the supporting girders carrying the saw-tooth frames should be kept at a minimum. With attention paid to these points, a proportion of height of window to length of span of the saw-tooth, in the ratio of 1 to $3\frac{1}{2}$, or 4, gives all

the light desirable in this climate, and if this ratio is exceeded I think it is at the expense of greater first cost for glass, and a greater running cost for heating, although special conditions may make the proportions given unsuited to a given case. The following photograph of a factory which the writer noted in Mexico is interesting in the fact that the fronts of the saw-teeth have a large part of the surface boarded up, and only a few sash are placed where we generally try to get all the light we can. This particular factory faced fairly to the south, and it is also interesting to note that direct sunlight was particularly undesirable in the processes carried on inside.

22 The three sheets of drawings (Figs. 1, 2 and 3) show types of saw-teeth framed in wood, with some details, which the writer believes meet

FIG. 5 RUBBER FACTORY IN NORTHERN MEXICO (FACING SOUTH)

the requirements of this latitude. Very little originality is claimed for these, as they are the result of experience gained in the examination of many different roofs designed by many different men, combined with the statements of those who have used the roofs and the experience of the writer's personal practice in trying to overcome some of the troubles which have been noticed or reported. Many of the members can doubtless suggest forms and details which they have used, and which meet conditions better than anything noted, and it is from these that the writer hopes to hear.

23 In closing I wish to acknowledge the courtesy uniformly shown me in gathering data for the paper, and to express my appreciation of the help rendered by my assistant, Mr. E. E. Hobbs, in preparing the drawings.

OUR PRESENT WEIGHTS AND MEASURES AND THE METRIC SYSTEM

An Argument for a Technical Commission

By HENRY R. TOWNE, NEW YORK, N. Y.
Member of the Society

Note: While this argument is addressed primarily to engineers, because their training and work imply familiarity with most of the technical facts on which chiefly it is based, and because of their intimate professional relation to organized industry in nearly all of its branches, it is intended to appeal also and equally to all other professions and interests. The questions at issue are national, not local; they affect all classes, not simply a few interests; above all they concern the plain people in their industries, commerce, agriculture and everyday affairs, not merely those whose work lies chiefly in the domain of science; they are intensely practical, not theoretical. The issues thus involved should be understood by all the people, and any laws affecting our weights and measures should be based, as all legislative enactments of universal application should be, on the intelligent and unequivocal demand of an unquestioned majority of the electorate.

1 Since 1816, when President Madison in a message to Congress stated that "no adequate provision has yet been made for the uniformity of weights and measures contemplated by the Constitution," the question thus implied has been frequently in a state of unstable equilibrium. On the one hand, usage and legislation by the States have established and confirmed our present system of weights and measures, but, on the other hand, the advocates of the metric system have persistently sought to secure its compulsory adoption. Congress in 1866 legalized its use and it has since been taught in our schools, and the development of modern science, especially in the field of electricity, has necessitated the creation of many new measures, which usually have been based on metric units. Is it not time, therefore, that the vitally important questions thus involved should be studied by a competent technical tribunal, whereby a decision may

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be reached, which, being based on due consideration of all the conflicting issues involved, shall be acceptable to all our people, and therefore, permanent?

2 Heretofore, except for informal discussions by unofficial bodies, the consideration of this subject has been limited to hearings by the Committees on Coinage, Weights and Measures of the two Houses of Congress, and to arguments by such individuals as have appeared voluntarily before them, usually as *ex parte* advocates of one system or the other. Very few of the members of such committees have been qualified by technical training and experience to pass on the complex issues thus presented, and until now no serious effort has been made to create a special tribunal of qualified experts to study and report upon the subject of our national weights and measures, and thus to provide a foundation on which Congress could construct legislation which would settle, wisely and permanently, this momentous question. In the hope of promoting the creation of such a tribunal, in order to point out its necessity and its great possibilities for usefulness, and to assist in an understanding of the issues involved, this paper has been prepared. The writer ventures to hope that the study of the subject during many years and an extended experience as an engineer and manufacturer may have given him some qualifications for the task.

A TECHNICAL COMMISSION

3 The argument herein advanced that a Technical Commission should be created to study and report upon the whole question of our Weights and Measures, its conclusions to form a foundation for action by the National Legislature, is justified by the example and experience of other nations.

4 France, suffering from the confusion of many divergent local systems, and after an agitation for *unification* dating from 1670, when Gabriel Mouton, a priest of the Church of St.Paul, at Lyons, published a book proposing a decimal system of measures based on a minute of the earth's circumference, adopted a decree, sanctioned by Louis XVI. on August 22, 1790, charging the Académie Française with the duty of determining "the scale of division which it believes most convenient for all weights, measures and coins;" and the Convention, on April 7, 1795, enacted a law, based on the recommendation of the Académie, confirmed and made effective by a later law of 1801, which embodied the metric system as it now exists, although many more laws were enacted and many years elapsed before the system was accepted by the French people for popular use.

5 Germany, suffering in like manner from different systems local to each of its many states, appointed a commission of scientists, which reported, in 1861, in favor of the metric system, which, however, was not adopted until after much further discussion, and the use of which did not become obligatory until January 1, 1872.

6 England, whose statutes show from early times a keen appreciation of the importance of fixing and maintaining standards of weights and measures, began in 1783, under the leadership of James Watt, to consider the question of reforming its system and of establishing an international system. The discussion thus opened was conducted in Parliament, by the Royal Society, and by other scientific and technical bodies, and has continued to the present time, but without resulting in any material change in the British system of weights and measures. In each of these three countries, and in others which have adopted the metric system, resort has been had to established scientific bodies, or to special technical commissions, for investigating the foundations on which to base constructive legislation.

7 In the United States, the Federal Constitution according to Act 1, sec. 8, par. 5, gives to Congress the power, "To fix the standard of weights and measures," although, as pointed out by Hallock and Wade in their recent volume, "The Evolution of Weights and Measures," this is, "almost the only power expressly and specifically conferred on Congress, which that body has refrained from exercising down to the present time." The importance of the subject was recognized in various papers by Washington, Jefferson, Madison, and especially by John Quincy Adams. The *Report upon Weights and Measures*, submitted by the latter, February 22, 1821, while he was still Secretary of State, is a masterpiece which is still quoted in almost every discussion relating to the adoption of the metric system by the United States. Even prior to 1831, steps had been taken to insure conformity of the U. S. Standards with those of Great Britain and uniformity throughout the Union, and by 1856 the various States of the Union had been supplied with duplicate standards, thereby establishing that practical *uniformity* of weights and measures which prevails today throughout the United States. This is one of our best national assets, and in the extent of territory and population by which it is accepted, to the absolute exclusion in industry and commerce of every other system, it is practically without parallel in the history of the world. This system, it may be noted here, is also identical, except as to measures of *volume*, with that in use throughout the British empire. By an Act passed July 28, 1866, Congress provided that "it shall be lawful throughout the United States of America to

employ the weights and measures of the metric system." Although it has thus been lawful, for more than forty years, for any one who so desires to use the metric system of weights and measures in the United States, the people have not seen fit to avail themselves of the permission, but, in their industry and commerce, have adhered, with absolute uniformity, to their established standards. The question which now exists, in view of the persistent agitation for the compulsory use of the metric system, is confined practically to a decision as to which of the following possibilities can most wisely be accepted, viz:

a The retention of our present system unchanged.
b The retention of our present system, modified and improved in its details.
c The adoption of the metric system.

8 As to the *first* and *third* of these possibilities opinions differ, but the choice between them can readily and intelligently be made by each individual if called on to decide, for the alternatives they present are definite and well known, although the far-reaching effects of the change involved in the third may not yet fully be understood or appreciated, but as to the *second* no intelligent decision can be reached until the changes which it implies have been formulated into a definite plan, and this can only be done properly by a competent commission or tribunal, qualified for the serious technical and scientific work involved. Before we discard our present system which, even if not perfect, has served us well, let us have a clear understanding of the improvements and corrections of which it may admit, so that we may contrast it in perfected form with the other system which it is proposed to substitute for it.

9 Such a commission, if created, should be authorized to include in the scope of its work *all three* of the possibilities above defined, in order that each may be duly considered and weighed, and that the report of the commission, when completed, shall cover the whole ground, and shall serve not only as a basis for final legislation by Congress, but also, by its scope, thoroughness, and fairness, as a safe and competent basis for that public opinion which should underlie every statute, and without which no statute, even if enacted, permanently can endure.

10 And now, having thus outlined the situation and the subject, let us proceed to consider some of the underlying facts which it involves, especially those which relate to the relative merits of our present sys-

tem and of the metric system. The questions thus involved are so numerous, so important, and so distinct, as to make it expedient to discuss each of them separately.

DECIMAL NOTATION

11 In connection with any system of weights and measures the method of notation which may be adopted has two chief uses; namely, (1) in the daily life of the people, and (2) in the work of scientists, accountants, and others engaged in calculations. By a law of nature man resorts in the first instance to binary division, that is to division into halves, quarters, and so on. His next most usual resort is to duodecimal division. His final resort, but chiefly for purposes of computation, is to decimal division, the conveniences of which are artificial, not natural or inherent in the use of ten as a base.

12 The reasons for this sequence of preference are inherent in the law of numbers, and are not difficult to analyze. The most simple and most common division of anything is into two parts or halves. Its repetition produces quarters, eighths, sixteenths, etc. A child or a savage desiring to divide an article into parts resorts naturally to this process of binary division; we cannot imagine that he would ever resort to decimal division, the use of which implies a higher stage of arithmetical procedure. The duodecimal system is also, but in a higher sense, a natural one, because its base of 12 admits of division into aliquot parts by the divisors 2, 3, 4, and 6. Nature has divided the year into 12 months. Man almost universally divides the day into two halves and each of these into 12 parts of one hour each. Twelve multiplied by 5 produces 60, which is the universal base for the division of the circle, of the hour, and of the minute. The Latin word for one-twelfth, *uncia*, is the origin of our words inch and ounce, indicating, respectively, the one-twelfth part of the foot and the pound. Even in metric countries the *dozen* is a common unit of quantity for the uses of trade.

13 Decimal notation is based on count by the fingers, not on the law of numbers, hence, the form of the Roman numerals. Unlike 12, 10 is divisible into aliquot parts by only two divisors, 5 and 2; for all other subdivisions, resort must be had to fractions. The feature of the decimal system which gives it its great convenience, the raising of any digit to a higher power by placing behind it a cipher or another digit, thus changing its "decimal place," is not necessarily limited to the decimal system; it could be used equally and as readily in the duodecimal system, by adding (as was suggested long ago) two digits to our present nine, so that a change of position would raise the power of

the digit by 12 instead of by 10. As was pointed out by the late John W. Nystrom, a still better base for a new system of notation would be 16, which would involve the addition of six new digits. The decimal system, however, is too well established to make it at all probable that it will ever be abandoned for another having a base either of 12 or 16, great as are the advantages which either of these offer, and, therefore, we may conclude that it must be accepted as a finality. Granting this, the effort should be, in constructing or revising any system of weights and measures, to arrange it so that binary division shall be available for all the ordinary purposes of industry, trade, and the people, and the decimal system available for the uses of scientists, accountants, and in abstruse calculations of all kinds.

14 Granting that decimalization is thus desirable, it by no means follows that it is necessary to resort to the metric system to obtain it. Any unit, or base of measurement, can be multiplied or subdivided decimally. This is already done, to a large degree, with the English measures of length. Surveyors have long found it convenient to divide the foot into tenths, instead of into inches or twelfths, and the subdivisions of the inch into hundredths, thousandths, etc., is practically universal in connection with all mechanical work involving refined measurements. For the mere purpose of obtaining decimalization we have no need to resort to the metric system.

15 The tendency of binary division to persist, even where the decimal system prevails most largely, is found in France, where the common unit of weight, the half-kilogram, known universally as the "livre" (or pound), is divided, for all purposes of trade, into halves and quarters, and where also the subdivision of the millimeter (when expressed verbally, but not when written) is frequently into halves and quarters.

16 To sum up, therefore, the effort as to notation in constructing or reforming a system of weights and measures, should be so to arrange the various scales or "tables' as to facilitate the use of binary and duodecimal division for the every day uses of the people, and yet to facilitate also the use of the decimal system for all work of computation; as, for example, at present we divide the inch into halves, quarters, eighths, and sixteenths, etc., for common use and in talking, but into hundredths, thousandths, etc., for fine work and in writing.

17 Unquestionably there is a needless confusion in the English system of measures. We have, all told, ten tables of measures, nine of which are in active use. Three of these relate to *weight*, viz: troy weight and apothecaries' weight, in which, however, the same pound, ounce, and grain obtain; and avoirdupois weight, in which there is a

relationship to the others arising from the identity of the grain. It would seem to be a comparatively easy matter for a competent commission to reconstruct our system of weights, without necessarily changing its base unit, the grain, and in place of the threefold system we now have to substitute a single one, with decimal subdivisions if found expedient.

18 In the matter of measures of *volume*, we have "liquid measure," with a gallon of 231 cubic inches, "beer measure," with a gallon of 282 cubic inches (practically not used now), and "dry measure" in which the bushel, unfortunately, has a fractional relationship to the cubic inch. Now it would seem that possibly these three measures might be merged into one, and further might be so standardized as to conform to the British imperial measure of the bushel, which is slightly different from the American bushel, whereas the British pound, foot, and inch are identical with the American. With the slight change thus implied, the British and the American units of weight and of volume would be brought into perfect harmony, and could be simplified into practically two tables or scales, one for weight and the other for volume.

19 In measures of *dimension*, we have nominally four tables; "long measure," covering all measures of length, in which the English and American base is identical; "surveyors' measure," which is arbitrary, although based on the foot, the surveyors' chain being 66 feet in length; and "square measure," used for measuring surfaces of land and other areas. From square measure is derived our "cubic measure." In all of these, likewise, it would seem clear that something may be done in the way of simplifying the tables, discarding needless units, such as the furlong, rod, and rood, and reconstructing the scales to facilitate both binary and decimal subdivision.

20 No such changes, however, even where they do not affect the base of the system, should be adopted until, after exhaustive investigation, the effect of the proposed changes, *on all industries and interests concerned*, shall have been duly ascertained, nor until all interests which would be affected thereby have had due opportunity to submit their views and to explain the difficulties, if any, which they believe would arise from the proposed action. The issues thus involved are serious, numerous, complex, and highly technical. For their proper study, and for the selection of a new, or the development of an improved system which shall fully harmonize all difficulties and reasonably respect all interests, a commission is needed which should be composed of men of training, experience, and recognized authority

in all of the many lines of industry, commerce, and science which are involved.

21 In considering the question of reconstructing our present system as to each of the several scales or "tables" of weights and measures, obviously the first step would consist in fixing the *unit* or base. This being determined, the next and final step would be to determine the multiples and submultiples of the base which may be convenient or necessary, and in determining these to aim to make available the system of binary notation for common use and a system of decimal notation for purposes of computation.

ABSOLUTE UNITS

22 The early units of measurement were usually based on nature, as for example, the foot, the thumb, a grain of barley, etc. Each country or district fixed its own units. Commerce was restricted and chiefly local. Divergence in weights and measures was thus of little consequence at first, but became more serious as industry developed and as commerce broadened and became international. Hence arose suggestions for the fixing of local and national standards, and finally for the creation of standards which should become international. The underlying motive throughout was a growing perception of the importance of *uniformity*, in place of the endless diversity which prevailed.

23 France, afflicted by a chaos of divergent local units, took the lead in the movement for uniformity during the period of its revolutionary upheaval, when idealism was rampant and at a time when modern industry was still unborn. It appointed a commission of scientists, in 1790, whose work culminated in the metric system, which was nominally put into effect in 1801. Many of the original features of the metric system were fanciful, impracticable, and were soon abandoned, as for example, the decimal division of the year, the month, and the day; of the quadrant, and of the circle. Even the base of the system, intended to be founded on nature and in the fixing of which infinite care was taken, was ultimately found to be erroneous. It is recognized now, however, that this fact is immaterial, that the meter is none the less an effective base for a system of weights and measures, because it is not an exact part of a meridian, and that the prime essential in any system is to have a base which is definitely determined and which shall not be changed. The metric system, as a whole, is logical, consistent, and has proved satisfactory for most uses, especially in abstract science. It has not proved entirely satisfactory in applied science, notably in the metal-working

and textile industries, but this is not surprising as these were in their infancy when the metric system was devised, and as no one representing them had any share in its devising.

24 What France chiefly needed and sought was *uniformity*, as is shown by the decree sanctioned August 22, 1790, which reads, "the National Assembly, desiring that all France should forever enjoy all the advantages which will result from uniformity in weights and measures, etc., etc." What France sought was thus *national unity* in her weights and measures. In accomplishing this, she sought also good units or bases for her new system of weights and measures.

25 Germany, also in chaotic condition, each of its 40 States having its own standards, followed the example of France by the appointment of a commission, in 1860, and by the adoption, in 1871, of the metric system. What Germany sought was likewise *national unity*, that is,uniformity of weights and measures throughout her boundaries. With the metric system already created, and proved by experience to be sound and satisfactory, and with that system already in use by France, her neighbor on the west and in many ways her most important competitor, she wisely decided to adopt the metric system rather than to create a new one of her own, and thereby to secure not only national, but also partly international unity. Practically like conditions have existed in the case of each of the so-called "metric countries," that is, those which have adopted, officially at least, the metric system. The primary motive has been to substitute fixed standards and uniformity for uncertain standards and diversity. *Finding the need of a change*, they have wisely availed themselves of the metric system, scientifically constructed, successfully tested, and already adopted by many other countries. This is emphasized by Hallock and Wade, who say (p. 82): "When we join to these considerations the fact that the separate systems in nearly all cases were illogical, inconvenient, and lacking in uniformity and facility of use, we have the explanation of the eventual spread of the metric system in Europe."

26 In the case of the United States, however, no such impelling necessity exists. As previously stated, we now possess *fixed standards* and *national unity*. In other words, we already have those blessings the want of which has led other nations to adopt new standards. Still more, we have also international unity (except as to measures of volume) with the whole of the British Empire, with commercial China and with many other countries, all of which we would sacrifice, temporarily if not permanently, in case we should abandon our present system.

27 Now, are the French, or metric units, better than ours, and if so, are they sufficiently better to justify the rejection of the latter in their favor? As stated by John Quincy Adams in his ever memorable report of 1828, on the question of adhering to our present system or adopting the metric system, "The first position which occurs as unquestionable is, that change, being itself diversity and, therefore, the opposite of uniformity, cannot be a means of obtaining it, unless some great and transcendent superiority should demonstrably belong to the new system to be adopted, over the old one to be relinquished."

28 As to Length. The meter has been found to be too long a unit for most industries, except the textile, in which it and the inch both prevail. The millimeter is too short for ordinary measurements, and too long for fine ones; the inch and its decimal divisions are better, while in the building trades the foot is preferable to the meter. The kilometer is good, but not better than the mile, to which its ratio is .62137.

29 As to Weight. The kilogram is about double the pound, and experience has proven that it is a less convenient unit than the latter. For the common uses of the people the French discard the kilogram, taking its half part, which they call call a "livre," or pound, and which they then divide into halves and quarters. The gramme is equal to 15.432 grains and, with its subdivisions, probably a better unit than the grain. The tonne is practically identical with our ton of 2240 pounds, its ratio to the latter being 1.016.

30 As to Volume. The liter is almost identical with our quart. Our larger unit, the gallon, is perhaps more convenient for many uses, but either is good. The hektoliter is equal to 2.8375 bushels and would seem to be too large, although its tenth part coincides closely with our peck.

31 As to Area. The hectare is equal to 2.471 acres. As a unit, this is too large and the acre is better.

32 Certainly this comparison fails to show any marked preponderance in favor of the metric units; if anything, it would rather prove the reverse.

33 It is conceded that in their *inter-relations* the metric units have a marked advantage, and constitute collectively a more scientific and logical series than exists in any other system. This fact, however, while of great interest to scientists and of great practical benefit in their work, does not interest the common people, has no bearing upon the transactions of their daily life, and does not constitute any just ground for attempting to force upon them new units which, for

their uses, are less convenient than those they now have, especially if this change would carry with it little or no compensating gain.

34 This argument against a change in the basic units by no means implies, however, a corresponding objection to a revision of the scales or tables which embody the multiples and submultiples of the basic units. It is conceded that these tables, as they exist in the English system of weights and measures, are needlessly complex and numerous, and could easily be simplified, to their great improvement, without at all disturbing or changing any of the basic units. But this is a totally different proposition from a change in the basic units. It would involve no change in habits of thought, and little or no change in the mode of expressing the daily transactions of the people, whereas a change of *units* would be subversive of both and of all records and expressions used in the current transactions of life as to everything in which our weights and measures are involved.

35 The utter failure, which commonly prevails, to realize what such a change would mean was shown by Mr. Littauer, the author of the latest bill in Congress for the adoption of the metric system, who, in his testimony before the House Committee on Coinage, Weights, and Measures, March 22, 1905, said, "Of our 80 millions people, 70 millions would learn such measures (of the metric system) as they would need probably within a day or two." Such a statement is pure empiricism, opposed by all experience of the past, and disclosing complete ignorance of the subject. As a contrast of experience with empiricism, may be cited the statement of Major F. A. Mahan, U. S. A., a prometric advocate, who admits that, although he has "employed the metric system largely for 30 years," he has always "experienced difficulty in *thinking* in the system." That is, he has had to translate from the metric system into the system with which he has been familiar from childhood.

36 So far, therefore, as the question of absolute units is concerned it has not been shown that those of the metric system, the meter, the kilogram, the liter, etc., have any inherent superiority to those of the British and American system, the foot, the pound, and the quart (or gallon), sufficient to constitute a reason for the abandonment of our established units in favor of those of the metric system.

MEASURES OF LENGTH

37 Between measures of length and measures of all other kinds there is an organic difference which it is of vital importance should fully be recognized in the consideration of the subject under discussion.

38 Measures of value, weight, and capacity are used chiefly in commerce and the transactions of daily life, all of which are transient; but measures of length relate chiefly to applied science; that is, to organized industry, the transactions and results of which are not transient but more or less permanent. In the expressive phrase of Mr. Halsey (in "The Metric Fallacy," by Halsey and Dale), they are, "linked irrevocably to the past," They *exist*, they are imperishable, and many of them never will nor can be changed so long as the things to which they apply shall endure. Among those thus referred to, may be specified the following:

All existing structures.
All existing machines.
All existing railroad equipment.
All existing interchangeable parts, such as screws, nuts, piping, shafting, couplings, etc.
All the existing vast equipment of special tools, gages, etc., of the metal-working industries.
All existing land areas and titles.

39 To change the monetary unit of a country involves some temporary inconvenience, but no permanent or serious disturbance. Transactions in money relate chiefly to the present, or to the immediate past. A change of this kind has successfully and easily been made, within the past century, by nearly all of the chief commercial nations.

40 To change the unit of weight would also involve some temporary inconvenience but nothing more, with the important exception of technical records and scientific work. Outside of these latter, transactions involving weight are matters chiefly of the present or of the immediate past. The same is true of the unit of volume or bulk.

41 But for us to change our unit of length would be to undermine the whole fabric of our vast mechanical industries, to disorganize our technical science, and to cause an actual destruction of values and of vested rights which would be colossal in its extent and almost infinite in its effects. The reasons for this are overwhelming; they are already abundantly on record, and will be referred to later. The variation in length of the British yard has been "scarcely more than a hundredth of an inch" *in the last four hundred years.*

42 Why should this revolutionary and destructive change be made? Who urges it? Not the interests chiefly and directly concerned, and which would have to foot the bill—the organized industries of the country—but theorists and scientists, sincere beyond doubt, but without practical experience in the matters chiefly involved, on whom none of the vast loss would fall. Possibly the ultimate bene-

fit of the change which they urge might be so great and far reaching as to outweigh the enormous waste and loss which certainly would be entailed, but neither of the groups so aligned on opposite sides in this controversy is competent alone to weigh the evidence and to settle this question. Each is prejudiced, and their interests are opposed. Calm, thorough, and skilful investigation of the whole vast subject, by an impartial technical commission, is the only possible way by which to reach a decision which shall be sound and just to all interests, and which will stand the supreme test of experience and time.

43 Since 1866 the use of the metric system has been legal in the United States. Any manufacturer who so chose has been free to use it. With insignificant exceptions none have chosen to do so—they do not want it—and yet theorists and scientists, who find it useful in *their* work, would force its use on others who have neither the need nor the desire for it, and who believe that its enforced employment would be a vast and lasting injury to them. Legislation of this character would be paternalism run mad. Our laws should be made *by* the people, not *for* them.

44 Those who seek to change our unit of length by arbitrary legislation, which would substitute the metric system for our present system, have thus far attempted only to secure a law which would make the use of the metric system compulsory in the transactions of the Government, but the author of the latest of these proposed laws, Mr. Littauer, in his testimony concerning it before the House Committee on Coinage, Weights, and Measures, said frankly, "I hope it will be the entering wedge towards the adoption of the metric system generally." This is the avowed end in view with all pro-metric advocates who have honestly expressed themselves, and, therefore, may fairly be assumed as the ultimate purpose of their efforts. I repeat that legislation of such vast importance, and such far reaching effect, should be based on the most careful and competent expert investigation, and upon an unmistakable popular demand. *No such demand exists.*

45 The transition from our actual system to the metric basis, in measures of length, might have been comparatively easy one hundred years ago, when modern industry was just starting upon its marvelous career, but would be infinitely difficult now in view of the vast present development of that industry, nearly every implement of which is based upon our established unit of length. In France even now, after more than one hundred years, some of the old units of length still persist, especially in the textile industries, as shown conclusively by Mr. Dale. In Germany, after forty years, this is also true and in a greater degree. Mr. Henry Hess, of the German Niles Tool Works,

Berlin, says (1902): "The Rhenish inch is nearly universally used in the building trades." a statement which the writer verified in 1903. France adopted the metric system in 1801, and Germany in 1871. If the United States should adopt it in 1906 how many years, how many *generations*, would have to elapse before our present standards of length, the foot and the inch, would disappear and be replaced completely by the meter? So long as they might persist, we would have confusion where we now have absolute unity. Surely the endorsement of a competent technical commission should precede any serious action in the direction of such a change. The manufacturing industries of the United States and Great Britain combined have far more capital invested in plant, machinery, and implements based on the English inch than have the corresponding industries of all the so-called metric countries based on the meter. The units of weight and of volume may be changed without great or lasting disturbance of those industries, but not the unit of length.

46 To change the unit of length would be to substitute variety and confusion where now we have absolute uniformity throughout the Anglo-Saxon world. Whatever may be the plea of the scientists in this regard, that of the manufacturers may be summed up in four words, "Let us have peace." As is well said by Hallock and Wade, (p. 174) "it remains for the adherents of the metric system to convince the manufacturing public by demonstrating its (the metric system) superiority for their work."

UNIFORMITY

47 The chief and strongest argument of those who advocate the adoption of the metric system is that thereby we shall attain to greater uniformity than we now have, because thereby we shall conform our practice to that of the countries which have adopted, successfully and completely, the metric system. Let us see what are the facts under this head.

48 *No country in the world*, except the United States and the British Empire, now has complete uniformity in its weights and measures. In nearly all of the so-called metric countries the old measures are the measures of the people, and the metric system is used only by the government, by scientists and in commercial transactions of the larger kinds. In the United States and the British Empire, on the contrary, absolute uniformity as to all weights and measures exists throughout each, and is international between them except only as to measures of volume, that is, the bushel, and the gallon, in which unfortunately, small differences exist between the two standards.

Should we adopt the metric system, even for Government use only, thereby we would destroy our present uniformity and would inaugurate confusion. Says Mr. Adams, "Is your object *uniformity*? Then, before you change any part of your system, such as it is, compare the uniformity that you must lose, with the uniformity that you may gain, by the alteration."

49 In confirmation of this argument, the following figures are submitted showing the relation of population to manufacturing industries in the chief industrial countries of the world.

	Population Millions	Total Mftrs. Millions
United States	82,6	$7,022
Great Britain	43,5	3,990
British Colonies (except india)	23,9	?
Group A	150,0	11,012
Per capita		$73.
France	39,0	2,360
Germany	56,4	2,837
Group B	95,4	5,197
Per capita		$54.
Austro-Hungary	48,6	Figures lacking, but if $54 per capita, a most liberal and probably an excessive assumption, they would aggregate $5,810
Italy	33,2	
Belgium	7,0	
Scandinavia	10,1	
Holland	5,4	
Switzerland	3,3	
Group C	107,6	$5,810
Then, totals of Groups B and C would be	203,0	11,007

Thus, while groups B and C combined show a greater total of population than group A in value of manufactures they barely equal it.

50 The adoption of the metric system by other countries is no proof of its inherent soundness or merit, but only of a desire to secure the possession of one or more of three obvious *desiderata*, viz:

a Fixed standards of weight, volume, and length.

b National uniformity as to these standards.

c International uniformity as to these standards.

51 Naturally and usually the smaller states, in adopting new standards have adopted those of the larger states, especially if con-

tiguous, as for example, Canada has adopted and uses the American dollar as its monetary standard. The larger nations which have found it desirable to change their standards have done so, in every case without exception, primarily to obtain *uniformity* in place of a chaos previously existing, and, being continental nations, have wisely adopted the metric system, previously devised and brought into effective practice by France, rather than the British system, or than evolve a new and original system of their own. But neither the United States nor Great Britain has any such need or motive for change. Each already has that which other countries chiefly sought in making the change, *uniformity*, and by changing they would lose it.

52 The argument is made that out of thirty-nine so-called "civilized" nations, thirty-six have adopted the metric system (although most of them for Government purposes only), the remaining three being the United States, Great Britain, and Russia. In reply it may be pointed out that the combined population of the three latter countries is 567,000,000 and of the remaining thirty-six countries only 445,296,000. A larger population exists within a radius of fifty miles from the Town Hall of Manchester, England, than in any one of the first twenty-five of the thirty-six nations referred to, and the combined population of twenty-four of them is only equal to that of the United States.

53 Measured either by industry or by commerce, the English units of measurement are in use today at least as extensively, and probably much more so, than those of the metric system. Measured by colonizing and assimilating power, the Anglo-Saxon race, which uses the pound, gallon, and foot as its standards of measurement, far outranks all the countries which use as their standards the kilogram, liter, and meter, combined. To the former already belongs the premiership in trade, in influence, and in control of the undeveloped and backward races of the world, having a combined population of over 600,000,000, not counting any of the so-called "Latin" countries, Russia, or the subordinate States of European powers.

54 We now *have* uniformity. Should we not hold it as a priceless treasure?

INFLUENCE ON DOMESTIC OPERATIONS

55 As pointed out before, the transition from our present system to a new one would be relatively simple and easy as to measures of weight and volume, but not so as to measures of length and area. As to each there would be inevitably a period of confusion while the people were learning the names and beginning to learn the values of

the new units, but in time they would acquire and use the new system. In matters involving measures of length and of area, however, a far greater obstacle would have to be overcome, namely, the difficulty of effecting the transition from the old to the new basis. The old units would *exist* in every machine, in every structure, and in innumerable articles of daily use, and no matter how superior the new system might be to the old, the impossibility of immediately bridging the gulf between the two would remain.

56 What advantage in our domestic industry and trade could be expected from the substitution of the metric for our present system? As shown above, the metric units as a whole are no better than ours, and those relating to length and area are inferior. The law of 1866 legalized the use of the metric system, and those who prefer it are already at liberty to use it. What is there in the existing situation to justify further legislation intended to make the use of the metric system *compulsory* on the Government as an entering wedge for the avowed purpose of ultimately forcing its use upon the people? A law so revolutionary in its character should only be enacted in response to a clear, if not an overwhelming, public demand. No evidence is adduced to show that any such demand exists. As has well been said by Mr. J. E. Hilgard, of the U. S. Survey, "It has ever been the practice of the Anglo-Saxon people to make laws in conformity with customs, not to create customs by compulsory laws."

57 Although the manufacturers of the United States were authorized in 1866 (since which date their collective export business has enormously increased), to use the metric system, not one in ten thousand has found it necessary or even expedient to do so, and if appealed to they would oppose overwhelmingly a proposition to coerce them in this respect. On the other hand scientists, chemists, and, to a certain extent electricians, opticians, and others, have found it convenient to use the metric system, and increasingly are availing of it in their work. Each group knows its own needs best, but neither should seek to coerce the other.

58 If we should adopt the metric system our old units would persist for generations. This is the case in France, after one hundred years and in Germany after forty years, although in these cases the change was made when modern industry was in its infancy or comparatively undeveloped. People *think* in their units of measurement and cannot translate mentally into strange units, especially in the transactions of daily life. The difficulty thus implied indicated by the mere statement of the exact metric equivalents for a few of our familiar units, *e. g.*,

A two-cent postage stamp equals in value 0.10336 franc.
1 mile equals 1.60934 kilometer.
1 pound equals .45359 kilogramme.
1 quart equals .94636 liter.

How long would it be before any of us could *think* in these unfamiliar units, or use them correctly without constant reference to the tables of equivalents?

59 Even metric advocates admit that we could not change our system of land measurements; that the acre as the basis of land records would have to be maintained. Their belief is justified by the experience of certain of our southwestern States, where French and Spanish units persist in transactions relating to land, and by the familiar fact that certain old records in Philadelphia, based on the accident of an inaccurate surveyor's chain, are still maintained. But these admissions imply that the adoption of the metric system would involve not unity but a *dual system*; confusion in place of order.

60 The same argument applies in the vitally important matter of screw threads. *These underlie almost every mechanical industry*, and are almost as impossible to change as land areas. Two systems of screw threads now dominate the mechanical world, the United States or Sellers, and the British or Whitworth. A feeble effort has been made to promote the adoption of a third, a metric system of screw threads (proposed at Zurich, in October, 1898), but even in metric countries the use of one or both of the other systems prevails today.

61 In the metal working industries a vast investment has been made in special tools, implements, and gages for the economical production of work on the interchangeable basis, all of which are based absolutely on the English inch as the unit of length. Only an insignificant part of this equipment could be converted to the metric basis. If the latter prevailed, this vast equipment would need to be duplicated to conform to the changed dimensions of the product. Pro-metric advocates, unskilled in the art, allege that all that would be needed would be to redesignate, in metric terms, each old article, without changing its dimensions. Those who know best will realize the unsoundness of this argument. For example, the actual dimension of a certain part of the well known Yale lock is .51 inch, and the permissible variation from this standard in either direction is one one-thousandth inch. The metric equivalent of .51 inch is 12.954 millimeters. Obviously the latter would be an inconvenient and almost unworkable dimension to maintain; obviously it would be desirable to change it to 13 millimeters. But this would be an enlargement of almost two one-thousandths of an inch, which is inadmissible. The old size

would persist, or if discarded, new tools and gages would be required. Millions of similar examples would be brought to light by due investigation. As stated by the writer, when a witness at one of the recent hearings before the House Committee on Coinage, Weights and Measures, 'One thousand millions of dollars would not cover the ultimate cost to the manufacturers of the United States of the compulsory adoption of the metric system in the resulting changes in their equipment of machinery, tools and gages.' It would hardly be an exaggeration to state that in some cases such an enforced change would mean bankruptcy to the manufacturer. Dr. Coleman Sellers has testified that the cost would approximate two hundred dollars per employé. Mr. Tannett-Walker of Leeds, England, places it at fifty to seventy dollars per employé. Mr. McFarland, Vice President of the Westinghouse Electric and Manufacturing Company, places the amount, for their Pittsburg works only, at $650,000. If the number of employés in the metal working and allied trades be assumed to be only 5,000,000, and the cost per employé only $100, the aggregate would be $500,000,000. And yet, Mr. Littauer (author of the last pro-metric bill) *thinks* the cost might amount to $1,500,000!

62 France, in 1801, had no such conditions to deal with, nor did Germany even in 1871. Modern industry, especially in the United States, is largely the creation of the last fifty years. What might have been easy in 1801, or feasible in 1871, has become almost impossible in 1906. The proposed change would vitiate all existing Anglo-Saxon engineering literature. The thousands of engineering formulae and multitudes of tables, and the vast records of past experience, are all stated in terms of our existing standards. All would have to be rewritten and translated into unfamiliar terms to make them available for use in practice in which the metric system would form the working basis. But engineers, and all other designers and constructors, *think* in their established units of measurement. They cannot think in others which are unfamiliar, but can only translate from the former to the latter, at great cost of time and trouble, and with still greater risk of error. On this point we may quote a pro-metric writer in "Science" for August 5, 1904, who frankly admits that "Reasonably complete assimilation will take several generations . . . . none of us will live to see any better than good progress on the part of the public." So also Mr. E. R. Briggs, of Rugby, England, a pro-metric advocate, who has long used the metric system in his own work, in a paper read October 6, 1905, admits that, "It may be taken for granted that the end of ten years, nay one hundred years, would still see the existence of the Imperial (British) system." Surely on the facts thus

disclosed the endorsement of a competent technical commission, based on an elaborate and impartial investigation of all the facts, should precede any proposal for the compulsory adoption of the metric system in the United States. Such a commission could also properly give due consideration to the argument, so frequently made but as often disputed, that the adoption of a decimal system, in place of our present mixed system of weights and measures, would result in a large saving of time now wasted, both in school and subsequently in the actual transactions of commerce and industry.

INFLUENCE ON FOREIGN OPERATIONS

63 It is urged, as a *chief argument* in favor of the metric system, that it would promote our export trade. If true, this is an important factor which should have due weight, but is it true? For reply we can only look to experience. What does this teach? Has the non-use of the metric system retarded the growth of our exports of manufactures? In 1895 they were $40,000,000 or 12.76 per cent of total exports; in 1905 they were $543,000,000 or 36.44 per cent of total exports. During this period of ten years our exports of manufactures increased thirteenfold, and their percentage of our total exports increased threefold. Would these increments have been greater or more startling had we adopted the metric system?

64 Has the non-use of English measures by France, Germany and other metric countries operated to decrease our imports of manufactures from such countries? If they should abandon the metric system tomorrow, and substitute for it the British-American system, would our purchases of their manufactures thereby be increased?

65 As a matter of fact there is no recognized or visible demand from our export merchants, or from the foreign merchants to whom they sell, that we should discard our present system of weights and measures and adopt the metric system. As has well been stated by Mr. J. E. Hilgard, of the U. S. Coast Survey. "Until all nations use the same language and the same money but little is gained in the way of unification of values by making the units of weight and dimensions alike." And another writer, Mr. G. W. Colles, makes the following pertinent observations, "While other nations, anxious to gain perfection at a stride, have hurried from one expedient to another, the steady plodding of the Anglo-Saxon race has placed them far in the lead among commercial nations; and rendered it self-evident that, so far as *language* is concerned, notwithstanding any theoretical advantages which others may claim, and the scorn which may be offered to its uncouth spelling and illogical pronunciation, if any one language

is ever destined to supplant all others, the English must be the one. And if the same supremacy which has followed the English language and other institutions does not follow also their system of weighing and measuring, it is at least much too early to predict it of any other." (Transactions of the A. S. M. E. 1896, p. 528.)

66 In this connection the figures in the following table are pertinent.

FOREIGN TRADE OF THE UNITED STATES, FOR THE YEAR ENDING JUNE 30, 1905

	IN MILLIONS OF DOLLARS	
	Exports	Imports
Total foreign trade	1,518	1,117
Great Britain and British Empire	741	330
Ratio to total	49%	29%
British Empire, China and Russia	820	370
Ratio to total	54%	33%
All other countries	698	747
Ratio to total	46%	67%

67 The above figures show clearly the preponderance of value to the United States of our export trade to Great Britain and her colonies over that to all other countries of the world, and the British markets are usually superior to others for manufactures of the medium and higher grade, in which we chiefly excel. China is our best customer for textiles, and in 1905 bought them to the value of $33,849,717.

68 The writer, speaking from personal experience in the export of certain American products to all parts of the world, can state that during more than thirty years of such experience no instance has occurred in which our use of English units has interfered in the slightest degree with such business, nor in which any demand has been made for the employment in such business of the metric system. It is his conviction that our adoption of the metric system would not perceptibly increase our exports to metric countries and that it would handicap our export trade to other countries which offer us the largest markets. So long as England maintains her present standards we would need to maintain our existing units of measurement, wholly or in part, for all goods made for British markets, which, as shown in the foregoing table, constitute 49 per cent of the total. This would intensify and prolong the persistence of our old units, and would retard immensely the acceptance and use of the metric units. The result would be little or no gain to our export trade to metric countries, some damage to our trade in British countries, and a great increase of

confusion from the loss of that perfect uniformity which now prevails in our weights and measures.

69 Surely in this respect, also, the findings of a competent commission, based on a thorough investigation of all the many branches of industry and commerce which are concerned, should precede any alteration of our present system of weights and measures.

INFLUENCE ON GOVERNMENT OPERATIONS

70 No effective argument has yet been offered that the government would, in any way, directly or indirectly, be benefited by the adoption of the metric system. Mr. Littauer, the author of the latest metric Bill in Congress, in urging its passage, said, March 22, 1905: "The only object in making it compulsory on the Government (to use the metric system) is that the people throughout the United States may begin to get some practical experience of the metric system, in order that they may determine, at some future day, whether or not they will demand its compulsory use throughout the country." Is there an overwhelming demand by "the people" for any such paternal action by the Government? Are they so dissatisfied with their present right to use the metric system, and their present liberty to use either system, that they demand to be restrained from using the one and coerced into using the other, even in their transactions with the National Government? Absolutely no proof of any such demand is offered. Heretofore, "the people" have regarded this question as academic, rather than practical, and simply have not been interested. If the danger of coercion should become real, they may be depended on to speak and in no uncertain terms.

71 Plainly stated, the recent Bills for the compulsory use of the metric system are intended by their authors to educate the people to understand what they should, but do not, desire. Is this a proper function of our Government? Certainly it is not government by representation, for no member of Congress has ever yet had any mandate from a majority or even from an appreciable minority of his constituents to propose, still less to promote, such a law.

72 Has any other great country ever changed its system of weights and measures, or even forced its officials to use alien standards, simply by legislative enactment not based on previous thorough investigation by some technical commission or other expert body? France, under Louis XVI., in 1790, through the National Academy, appointed a large commission of the most distinguished scientists, among them Lagrange, Laplace, Condorcet and Lavoisier, who, taking eleven years, reported finally in 1801. Germany, in 1860, appointed a tech-

nical commission, whose work a'so occupied eleven years, and was completed in 1871. Shall we, with no such chaotic conditions to justify a change as confronted them, ignore their example and attempt this momentous change by a simple act of Congress, without any scientific and expert previous investigation? Such a proposition implies an utter want of understanding of what such a change would mean, and the complete disjointing of our industries which would follow. Where is the resulting benefit, or what the excuse, to justify such precipitate and informal procedure in a matter of such vital and lasting mportance?

73 Turning now to the effects of such a change on the business transactions of the Government itself, the following may be pointed out as conditions which should at least be studied carefully before we commit ourselves to such a momentous change, viz:

a It would disqualify for a long time probably 95 per cent of the present army of Government clerks from doing their work efficiently.

b It would for many years add greatly to the time and cost of all government accounting, and to the army of Government employés.

c It would greatly increase the tendency to error.

d It would make the Government reports for a long time unintelligible to the people.

e It would preclude comparison of past with future records and statistics.

f It would preclude ready comparison of our statistics with those of the British Empire.

g It would make void the engineering and technical formulae which our Government engineers (Army and Navy), naval constructors, architects, etc., have used all their lives.

h It would compel the Government or the seller, in every transaction, so long as the metric system was used by the Government only, to express every detail of such transaction in terms of both systems.

i It would compel the Government, in order to obtain commercial products, to describe them in alien terms but in intermidable fractions, *e. g*;

A bar of 1 in. iron as 25.4 millimeters;

A $\frac{7}{8}$ in. bolt as 22.225 millimeters;

A 12 in. plank as 304.8 millimeters, or as 0.3048 meters;

A ton of coal as 1.016 tonne;

A gallon of oil as 3.785 liters, etc.

j It would cause the small manufacturer and dealer to reject Government business.

k It would increase the trouble and cost of doing all business with the Government.

l It would create confusion and disorder where we now have uniformity and order.

m It would change the readings of all coast survey charts.

n It would compel an entire revision of the terms used in Dingley Tariff Bill.

74 Surely these vast changes, affecting the work of every department of the Government, and every detail of that work, should most carefully be considered and reported on by a competent commission before we commit ourselves to the compulsory adoption of the metric system, even for use by the Government only.

CONCLUSIONS

75 In summing up the conclusions to be deduced from the preceding arguments, we cannot do better than to quote the warning of John Quincy Adams, in his report of 1821, "If there be one conclusion more clear than another, deducible from all the history of mankind, it is the danger of hasty and inconsiderate legislation upon weights and measures." To this may properly be added a quotation from a paper submitted to the December, 1896, meeting of The American Society of Mechanical Engineers, by Mr. George W. Colles, as follows: "If there is to be a compulsory law of any kind, let it be one compelling the national legislature to leave this matter alone until we can have it decided by a competent and practical commission, appointed from the people."

76 And, again, a Select Committee, appointed by the Parliament of Great Britain, reporting in 1862 in favor of the metric system, added that "No compulsory measures shall be resorted to until they are sanctioned by the *general conviction of the public.*"

77 One Congressional committee after another has considered this problem and attempted, in good faith but unsuccessfully, to solve it, each of them failing to realize that its essentially technical and many-sided character precludes effective action by a political committee, however talented and earnest its members, and that an essential preliminary to safe action by Congress or any of its committees is an impartial and exhaustive investigation of all the many issues involved by a technical commission, representative of all the great interests

involved, and unstinted as to time and opportunity, whose report shall serve as a basis for constructive legislation.

78 If such a commission is created its members should approach their work with open minds, unprejudiced and untrammeled, solicitous only of learning all the facts, of weighing all arguments, of hearing all interests, and of reaching conclusions which shall be sane, just, sound, and permanently right. Hitherto, the discussions have lacked that judicial atmosphere which their topic and their importance demand; have been too partisan in character and too narrow in scope. On the one hand the advocates of the metric system have sought to make its use compulsory at once by the Government and ultimately by the people, while on the other hand those who believe such a change would be unwise, and especially those who think their property rights would be injured by it, have been put to much trouble and some expense to defeat the efforts of the pro-metricists. Neither the proponents nor the opponents of the metric system are infallible, obviously both are prejudiced and each precommitted to one view of the case, and clearly the decision cannot be left to them. In the light of our own experience, and that of foreign nations, it seems equally clear that no legislative body, not even the Congress of the United States, can wisely undertake to deal with a subject so technical and so interwoven with all science, industry, and commerce, unaided by technical advice and by previous expert investigation; and, therefore, that we should now follow the precedent established by each of the great nations which has acted in this matter by creating a Technical Commission to which it shall be referred for investigation and report. In support of this view the writer frankly admits that the longer he studies this question, and the more he grasps its importance and its relation to all the varied activities of our people, the more he realizes that no individual alone is competent to deal with it, and that a safe and enduring solution of it demands the combined labor and intelligence of many minds, each qualified by previous special training and experience in science, industry, agriculture, and commerce, whose united judgment shall recognize, respect, and conserve all of the varied interests concerned.

79 While thus admitting the impropriety of deducing, from any investigation and presentation of the facts which has yet been made, conclusions as to what changes, if any, in our system of weights and measures are expedient and desirable, and while frankly avowing that his study of the subject thus far has led him to question the expediency of our substituting the metric system for our present system of weights and measures, and to believe that a better solution may

perhaps consist in reforming and simplifying the latter, with few if any changes in its basic units, the writer submits the following conclusions as justified by such facts as have herein been presented, viz:

80 Decimal Notation. The advantages of a decimal system are conceded for purposes of computation, but denied for the ordinary uses of the people. For the latter binary division always has and always will prevail. Decimal notation is feasible with any system. If finally we decide not to adopt the metric system, let us then reform our scales or tables, and in so doing decimalize them so far as found expedient.

81 Absolute Units. The metric units are no better than, if as good as, the units of the British-American system, and are equally arbitrary. The most important metric unit, that of length, is inconvenient. What is essential is that the units shall be definite and fixed. Next to this in desirability is that they shall be such that binary division shall be available for common uses, and decimal division for purposes of computation. The metric system fails to meet this requirement.

82 Measures of Length. These are organic, and are "linked irrevocably to the past." Many of them practically are immutable, such as those relating to land ownership, to construction, to screws, to interchngeable couplings, etc. Without great difficulty, we may change our units of weight and of volume, but not those of length or of area. To attempt to change the latter would entail vast losses, and would bring no compensating gain. The metric system is now legal in the United States, and yet unused. Of the organized bodies which have voted on this question, forty-four are on record as opposed to the adoption of the metric system in the United States, as against fourteen in its favor. The adoption of the metric system would mean, for a century at least, that we would have *two* systems of weights and measures where now we have only one. In reply to the argument for a change the plea of organized industry is, "Let us have peace."

83 Uniformity. We now have absolute national uniformity, and, except as to measures of volume, international uniformity with the British Empire. No other nation in the world, save Great Britain, enjoys today such absolute uniformity as to weights and measures as the United States. We may change our *scales*, if we retain our present base units, without losing this national blessing, but if we change our *units* of weights and measures, we shall substitute, for a hundred years or longer, confusion in place of the absolute unity we now enjoy. Other countries have changed their system to secure uni-

formity; we now have uniformity but would lose it if we should change our system. Let us make sure that the benefits to be secured by change would outweigh the difficulties and objections which any change of units implies, or else let us keep our present units.

84 Influence on Domestic Operations. The law of 1866, which legalized the use of the metric system, is all that is now justified; any further legislation would imply coercion, and this is contrary to the spirit of our laws. American manufacturers are free today to use the metric system but do not employ it, nor do they wish to be coerced into so doing. American scientists are equally free today to use the metric system, and are doing so. Let each respect the rights and interests of the other. No public demand for a change exists, and without it the change should not be made. The change, if made and if enforced, ultimately would involve a loss or injury to American manufacturers of probably more than $1,000,000,000, with no compensating benefit which they can perceive. The old units would persist in popular use for one hundred years or longer, during all of which time we would have confusion where we now have unity.

85 Influence on Foreign Operations. The enforced adoption of the metric system would not assist our export trade, but more probably would hinder it. Available statistics do not show that the nonuse of the metric system has retarded our exports of American manufactures, nor that the use of the metric system in foreign countries has decreased our imports of manufactures from such countries. No demand for the change has been made by our export merchants. Of our export trade in 1905, 49 per cent was with the British Empire, and in this trade the adoption of the metric system, if of any influence, would be harmful, not helpful. The net result of the change would be increased confusion, without any compensating gain.

86 Influence on Government Operations. The proposed change would greatly increase the operating expenses of all departments of the government, would almost destroy the value of government statistics for popular use, and would bring no compensating benefit of any kind. It would substitute confusion for the perfect uniformity which now prevails. Save the plea that it would give the people a basis of experience on which later to make a final decision, the proposal to *compel* the use of the metric system in all Government work has no argument to its credit, all of the arguments appearing on the debit side of the account. If investigation by a competent commission shall prove the contrary the change may be justified, but until then we should hold fast to the national unity which we now enjoy in our weights and measures.

REFORM

87 The opponents of the adoption of the metric system in the United States frankly admit the existence of many imperfections in our present system of weights and measures, but point out that these are not inherent in the *units* of the system, but rather in the multiples and submultiples of those units. Those who thus oppose the abandonment of our present system in favor of the metric system may fairly be asked, however, for constructive suggestions, especially if they admit the existence of crudities and imperfections in our present system. In fact they might well adopt the declaration of the British Weights and Measures Association, as to the objects which it seeks to promote, viz: "The Defense, Standardizing, and Simplifying of British (and American) Weights and Measures."

88 The Constitution gives to Congress the power "to fix the standard of weights and measures." But, says Mr. Adams, "It may be doubted whether under this grant of power is included an authority so totally to subvert the whole system of weights and measures, as it existed at the time of the adoption of the Constitution, as would be necessary for the introduction of a system similar to that of the French nation. To *fix* the standard appears to be an operation entirely distinct from changing the denominations and proportions already existing, and established by the laws, or immemorial usage."

89 The basic units of the British and American systems compare as follows:

Pound avoirdupois, 7000 grains; alike.
Pound troy and apothecary, 5760 grains; alike.
Linear inch, foot, yard and mile; alike.
Square inch, foot, yard and the acre; alike.
Cubic inch, foot, yard and the ton; alike.
Gallon, British 277.274; American, 231 cubic inches.
Bushel, British 2218.192: American, 2150.42 cubic inches.

90 The official standards of both nations are thoroughly established, and are in harmony. The reconstruction of our scales or tables, even though the basic units are left unchanged, would be a proper subject for governmental investigation and action, but in attempting such action, we should follow the example of France and of Germany, by referring the subject to a competent commission of technical experts, representative of all the sciences, arts, and industries, and should utilize the final findings of that commission as the foundation for legislative action by Congress. In thus organizing for the investigation of this most important subject, however, we

should seek not only to determine what shall be our permanent system, but, if the existing system is retained, to promote and maintain our present national *unity* as to weights and measures, and also, if possible, to bring about complete unity with Great Britain, whose weights and measures are already identical with ours save in respect to those of volume, the gallon, and the bushel. By international coöperation it should be possible to eliminate this element of difference, and to bring the weights and measures of the two great branches of the Anglo-Saxon race into perfect harmony; possibly also into some practical and helpful relation to at least some of those of the metric system.

91 The reader who has followed the argument set forth in these pages will perceive that it is intended to present and justify the plea in which it culminates, viz: that a Technical Commission should be created to which should be referred, for investigation and report, the whole subject of our weights and measures, including the possibility of improving our present system and also the expediency of substituting for it the metric system, the conclusions finally reached by this commission then to serve as a basis for legislation by Congress, and if necessary also by the several States. The writer has not attempted to conceal his present conviction that the disadvantages involved in abandoning our existing system of weights and measures for the metric system seem to far outweigh the advantages, nor his further conviction that our present system may be simplified and improved without disturbing the basic units on which it rests, but he recognizes with equal frankness the importance and vastness of the questions thus involved, the improbability that all of them can fully be appreciated by any individual, and the fact that a decision which shall be based on a clear understanding of all of the many sides of the question, which shall recognize and protect all of the many interests concerned, and which, being thus both sound and fair, shall command the approval and the permanent acceptance of the American people, can only be reached through the instrumentality of a commission composed of recognized experts in science, industry, agriculture, and commerce, to which should be accorded the time, the opportunity, and the means for pursuing its work in the most efficient manner and until the end in view has been attained. Therefore, when he appeared on behalf of the Merchants' Association of New York, as a witness before the House Committee on Coinage, Weights and Measures, on April 4 and 5, 1906, and made an oral argument against the then pending Littauer bill substantially on the lines of this paper, and when at its close he was requested, by a member of

that Committee, to draft and submit a bill which should give effect to his suggestions, he took pleasure in complying with that request, and subsequently, assisted by a friend versed in the law, submitted the draft of such a bill. That bill (H. R. 19,469) was introduced on May 18, 1906, by the Hon. Mial E. Lilley, and was referred to the House Committee on Coinage, Weights, and Measures. The text of the bill is given in an appendix to this paper.

92 The purpose of the argument herein presented is to call attention to the bill thus introduced, to insure a fair consideration of its terms, and to assist in an understanding of its purpose. The subject of our national weights and measures is one which concerns every citizen, and which has a direct and important relation to our national industry and national welfare. President Washington, in his first message to Congress, dated January 8, 1790, said, "Uniformity in the currency, weights and measures of the United States is a subject of great importance and will, I am persuaded, be duly attended to." His expectation was realized long ago as to our currency. Practically it has long been realized also as to our weights and measures, in which, as heretofore pointed out, we already enjoy absolute national uniformity. We are confronted, however, by the fact that a substantial number of our people honestly and sincerely believe that we should abandon our present system of weights and measures and should substitute in their place the metric system. These have urged, for many years and with great persistence, the change thus implied. Others, with equal sincerity and earnestness, oppose such change, although some at least of them believe that it may be possible, without changing our units of length and of weight and perhaps without changing even those of volume, greatly to improve our system of multiples and submultiples of these units, and at the same time possibly to bring about changes, either in our own system or in the British system, or both, which shall bring into complete and perfect harmony the weights and measures of both branches of the Anglo-Saxon race.

93 Surely, the trifling expense involved in the creation of the proposed commission, whether national or international, is abundantly justified by the promise it would hold forth of useful accomplishment in a wise and permanent solution of the problem of our national weights and measures. If so, it is to be hoped that all citizens to whom this plan appeals as the best mode of solving this important problem, will unite in approving and urging the creation of the proposed commission. If a commission is appointed there is good reason to believe that the British government, if invited thereto by the

President, will participate in the proposed work, either by creating a like commission or by appointing delegates to ours to make the latter international, as in the case of France in 1790, when five other nations were represented on the commission which finally reported in favor of the metric system. If the commission is appointed, and pending its final report, it may also be hoped that all further agitation of this subject, either in Congress or elsewhere, may be suspended. Let us have *light*, and then a *lasting peace*.

APPENDIX A BILL FOR A TECHNICAL COMMISSION

59th Congress, 1st Session. H. R. 19469. In the House of Representatives, May 18, 1906, Mr. Lilley, of Pennsylvania (by request), introduced the following bill, which was referred to the Committee on Coinage, Weights and Measures and ordered to be printed.

A BILL

Creating a commission to investigate the subject of weights and measures.

94 *Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That a commission is hereby created, to be called the Commission on Weights and Measures, which shall be composed, in the discretion of the President, of not less than nine nor more than fifteen commissioners, to be appointed by the President, by and with the advice and consent of the Senate, and to be selected from various professions and pursuits and in such manner that, so far as practicable, every important interest, particularly scientific, industrial, agricultural, commercial, mechanical, and maritime interests shall be represented thereon. Any commissioner may be removed by the President for inefficiency, neglect of duty, or malfeasance in office, and the President, by and with the advice and consent of the Senate, shall fill by appointment all vacancies which may occur in said commission.

95 SEC. 2. That it shall be the duty of the said commission to investigate and to report to the Congress upon the subject of measures of length, weight, and volume in use throughout the United States and in other countries, in order to enable the Congress to decide what action, if any, is feasible and expedient for the improvement of the system of weights and measures now in use in the United States, and to that end the investigations of the said commission shall include: First, the question of retaining or modifying any or all of the present standards of length, weight, and volume employed in the United States; second, in case present units are to be retained, the

question of improving and simplifying, especially for the purposes of computation, the subdivisions and multiples of such units; and third, in case any or all of such present units are to be discarded, the desirability and expediency of substituting therefor the so-called metric units and the system based thereon.

96 SEC. 3. That each commissioner so appointed shall receive a salary during his term of office of three thousand dollars per annum; that the office of the commission shall be located in the city of Washington, District of Columbia; that the commission shall give reasonable time for public hearings, if any shall be deemed necessary; that, if expedient, it may appoint a subcommission or subcommissions of its own members to make investigation in any part of the United States; that it shall have the authority to send for persons and papers and to administer oaths and affirmations. It shall be authorized to employ such assistants and clerks as it may reasonably require for the proper conduct of its work, and may fix the salaries to be paid to all persons employed by it, and that all necessary expenses, including the salaries of the commissioners, clerks, stenographers, messengers, rent for place of meeting, and printing and stationery, shall be paid from any money in the Treasury not otherwise appropriated, however, not to exceed one hundred thousand dollars per annum for expenditures under this section, to be paid upon vouchers to be approved by the chairman of the commission. That the commission is empowered to make all necessary, convenient, and proper rules and regulations of practice and procedure for the transaction of its business.

97 SEC. 4. That the said commissioners shall proceed with their work as rapidly as may be consistent with thoroughness and shall from time to time report the result of their labors and investigations to the Congress, and that when their work shall have been concluded the said commissioners shall embody the result thereof and their definite recommendations in a final report to the Congress; that their report shall be accompanied by notes which shall briefly and clearly state the reasons for the recommendations therein made and the legislation, if any, advocated by them.

98 SEC. 5. That immediately after the passage of this Act the President of the United States shall invite the Government of the United Kingdom of Great Britain and Ireland to participate in a conference for the improvement and unification of the standards of length, weight, and volume used by the United States and by the United Kingdom, such conference to be held at such place or places in Europe or in the United States as may mutually be agreed upon by the Executives of the two Governments, and that the President shall,

by and with the advice and consent of the Senate, appoint from the commission to be created under the provisions hereof, five commissioners to attend such joint conference on behalf of the United States. The commissioners so appointed members of such international conference shall receive a salary, additional to that provided under section three hereof, of two thousand dollars per annum and also their reasonable expenses as commissioners to such international conference, to be approved by the Secretary of State, said compensation and said expenses to be appropriated out of any money in the Treasury not otherwise appropriated.

APPENDIX B

99 Translation of an official letter from the Minister of Commerce, Industry and Labor to the Presidents of the Chambers of Commerce in the cities of France, illustrative of the persistence, even in that country one hundred and five years after its adoption of the metric system, of the older units of measurement. Furnished to the writer by Mr. Samuel S. Dale, and with his permission published herewith.

THE FRENCH REPUBLIC

PARIS, April 11, 1906.

The Minister of Commerce, Industry and Labor to
The President of the Chamber of Commerce at.....

100 My department at different times has been called upon to give to the Department of Weights and Measures instructions for accomplishing the total suppression of the measures and weights prohibited by the old law of July 4, 1837, by the seizure of the prohibited articles. The Department, in spite of all such efforts, has not succeeded in attaining the desired result. This situation appears to be due to the persistence with which certain trades continue to use the proscribed standards, their so doing leading to the use of the prohibited weights and measures.

101 I have learned that in certain industries the advertisements, prospectuses, catalogues, etc., used by the merchants, among themselves and also for sending to their customers, contain the illegal expressions. The merchants will invoke without doubt the necessity under which they find themselves not to change the existing order of affairs for fear that thereby they may lose orders for their goods. They thus continue to designate in lignes and inches all the articles they sell. It is true that in certain cases these measures are used rather to indicate sizes than for the purpose of invoicing merchandise.

Nevertheless the result is an objectionable usage which creates obstacles to the efforts made by my department to bring about the complete disappearance of weights and measures alien to the metric system, notably the division of the meter into inches and lignes.

102 I do not consider it worth while to enumerate here the industries and professions which have continued to employ the proscribed standards, but they are still numerous and most of them known to members of your organization. I do not think there is need to require from the agents of the Service a strict application of the provisions of Article 45 of the Ordinance of April 13, 1839, which requires them to report to the Recorder all violations of the law in regard to prohibited weights and measures which they may discover in advertisements and announcements. I recognize that if such a procedure were followed a considerable number of trades would be incommoded and much trouble be caused in the commercial operations of many manufacturers.

103 Under these conditions I have been led to make an investigation as to whether it is not possible to bring about a change in the present usage by some other method than that of repression, and therefore I addressed the Chambers of Commerce asking their members to use their influence both with commercial bodies and with merchants themselves to induce them to renounce practices which are contrary to the provisions of the law.

104 I am persuaded that the appeal thus made to them by the government will not find them indifferent, and that they will lend their assistance to bringing about the disappearance of the last vestige of the weights and measures in use before the creation of the metric system.

105 I shall be obliged to you for an acknowledgment of the receipt of this circular, of which I have sent a copy to the Inspectors of Weights and Measures, who being in daily contact with the manufacturers and merchants, can supply you with valuable information regarding the industries in your vicinity in which the old standards are still in use.

The Minister of Commerce, Industry and Labor,

GASTON DOUMERGUE.

A MECHANICAL ENGINEERING INDEX

By W. W. BIRD and A. L. SMITH, WORCESTER, MASS.
Members of the Society

1 Any one who has watched the industrial development of the last ten years has been impressed with the extended differentiation which has taken place. This perfecting of minor details of construction and the improvement of engineering methods has been attended with a corresponding growth in both descriptive and theoretical literature on the various subjects. One of the chief indications of this great increase in multiplicity of details, as well as of the fact that man's brain has reached its limit for retaining these details, is found in the popularity of the index idea. The recording and filing of the facts pertaining to a business or profession so that they may be instantly available, in other words, the construction of an infallible mechanical memory, has become one of the modern problems. To tell how one phase of this problem is being solved, namely, the building of a comprehensive Mechanical Engineering Index with a minimum expenditure of time, is the purpose of this paper.

2 The primary object of this index is to furnish references which will enable students and instructors in the Department of Mechanical Engineering at the Worcester Polytechnic Institute, to keep in touch with the latest and best literature pertaining to their special field. It is intended that this index shall be comprehensive, but select rather than exhaustive. To accomplish the latter, its material is furnished by the instructors instead of by students. No material goes on file which has not been reviewed by some one competent to judge of its value. The field covered comprises: Articles from Periodicals; Papers from Proceedings and Transactions of Societies; Theses; Book Reviews; Manufacturers' Catalogues and Trade Lists. All of the leading engineering papers, foreign and domestic, about thirty in all, are regularly reviewed. These are apportioned among the ten or more readers of the Department, so as to equalize the work and enable each man to have, so far as possible, the literature pertaining to his spec-

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ialty. The work is done at the reader's own convenience, and to secure uniformity and economy of time, a record is made on the special card shown in Fig. 8, those specifications necessary to describe the article being underlined. Inasmuch as the title of the article does not always indicate the matter for which it is recorded, the reader prints on the upper edge of the card the title and sub-titles which will determine its place in the index. Each reader is supplied with a list of the index titles which are printed herewith. The object of recording illustrations is to afford a clue to cuts suitable for lantern slides. An amber colored card is used for these references, as white cards are too easily soiled. These cards properly filled out are brought into the weekly Department meeting, and the articles having special interest are discussed in an informal manner.

3 The selection of index titles and their grouping will always create a difference of opinion. As has been stated, the reader determines under what title the article shall be filed. To illustrate: If an article on Pumps is of value chiefly as a general review of the subject, then it would be entered directly under the main title Pumps. If it were a general discussion of Power Pumps, it would find its place under Pumps—Power. If the chief value of the article was found in a record of tests, then it would be put under Pumps—Tests, even though the tests were of a single type only, such as Power Pumps.

4 Some Titles signify a single subject, as for instance, Lathes, while others signify several, as for instance Meters. Shall an article on Current Meters be filed under Meters—Current or shall it be filed under Hydraulics—Current Meter? In the same way, shall an article on Power Plant Chimneys be filed under Chimneys or under Power Plants—Chimneys? No rule can be formulated to cover all cases but in general it seems desirable to file under that title with which a subject is most closely affiliated. A general article on Chimneys would be filed under Chimneys, while one on the design of Power Plants as a whole but with some space devoted to Chimneys, would be filed under Power Plants—Design. An article on Crane Brakes would be filed under Cranes—Brakes. In the same way, it might be suggested that Steam Engines should be filed under Power Plants—Steam Engines, but in this case the subject of Steam Engines is of enough importance to make it a main title. And this might apply under certain conditions to any sub-title subject. Convenience for the user of the index rather than adherence to rigid classification should determine the question of grouping.

5 The problems involved in a catalogue file and index are somewhat different from those of a general reference index. Catalogues

should be filed so they can be quickly located, easily removed, and replaced without disarranging adjoining ones. As to the first, the great majority of catalogues have no back to which a label can be affixed. If the label is on the cover, and the catalogues placed on shelves like books, several may be pulled out before the right one is found. A tab made of gummed tape bearing the name or number of the catalogue and attached so as to project from its back will remove this objection. If the shelves have frequent partitions, the catalogues will stand up fairly well, but inasmuch as the catalogues are of different widths, some get pushed back and the others are easily disarranged. This last difficulty may be partially avoided if the catalogues are sorted into three common sizes and separate shelves assigned to each. A second difficulty presents itself when we attempt to index a catalogue covering a diversified line of manufactures. A steam engine catalogue takes care of itself, but one devoted to all kinds of machine tools, for instance, puzzles the indexer. To use a number of copies of the same catalogue filing one under each title is not satisfactory. Neither can the entire contents be indexed. Some system of numbering must also be provided which will permit proper grouping, expansion or contraction, and easy collating.

6 Several years ago the "American Machinist" advocated the following standard sizes for catalogues: $3\frac{1}{2} \times 6$, 6×9, 9×12. Most manufacturers follow these standards but many do not. In the catalogue file now described three sizes of drawers are provided to accommodate catalogues of these dimensions. A catalogue is filed in a drawer nearest its size. If the catalogue is a little too large, it is trimmed accordingly. This may sometimes slightly mutilate the catalogue, but seldom enough to impair its usefulness. From five to ten per cent of the catalogues that are filed may require trimming. Catalogues are placed in the drawer with their backs uppermost. A gummed label with suitable specifications, like that shown in Fig. 12, is put on that part which will be the upper right hand corner as the catalogue lies in the drawer. Selection, removal and replacing is thus rendered as convenient as with a set of index cards.

7 Various ways of designating and arranging catalogues have been used. One method is to number and file in the order of accession without reference to contents. This provides easily for expansion and collating and conduces to compactness. If, however, a user wishes to consult all the principal catalogues of Water Wheels, for instance, he will spend considerable time in selecting and replacing them as they will be scattered through the entire collection. Another method is to arrange alphabetically by manufacturers' names. For those that

are thoroughly familiar with the catalogues devoted to the different lines of manufactures, this makes a good arrangement, though it has the same defect as the previous system. Yet another way is to arrange alphabetically according to principal contents. A modification of this last is the one adopted.

8 A set of titles has been selected which covers those individual products or groups of products in which the Mechanical Engineer is directly interested. Blocks of consecutive numbers are assigned to each title, the range of numbers being in excess of the probable number of catalogues under that title. These blocks consist of 10, 25, 50, or

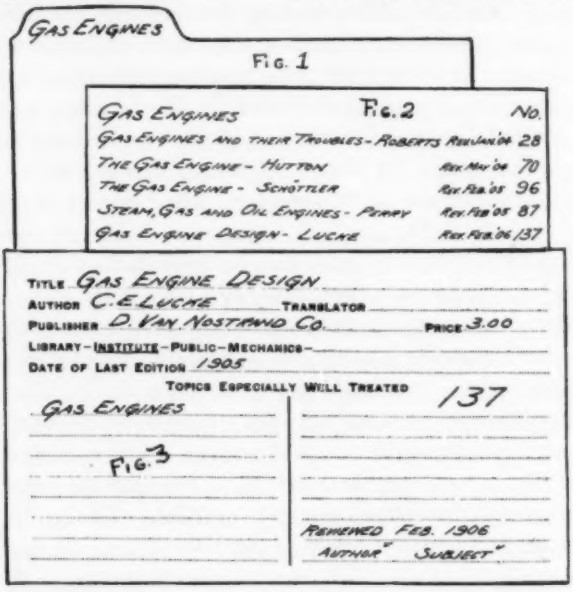
GAS ENGINES
FIG. 1
GAS ENGINES
FIG. 2
NO.
GAS ENGINES AND THEIR TROUBLES - ROBERTS REVISED 28
THE GAS ENGINE - HUTTON REV. NOV '04 70
THE GAS ENGINE - SCHÖTTLER REV. FEB '05 96
STEAM, GAS AND OIL ENGINES - PERRY REV. FEB '05 87
GAS ENGINE DESIGN - LUCKE REV. FEB '06 137
TITLE GAS ENGINE DESIGN
AUTHOR C.E. LUCKE TRANSLATOR
PUBLISHER D. VAN NOSTRAND CO. PRICE 3.00
LIBRARY - INSTITUTE - PUBLIC - MECHANICS -
DATE OF LAST EDITION 1905
TOPICS ESPECIALLY WELL TREATED
137
GAS ENGINES
FIG. 3
REVIEWED FEB. 1906
AUTHOR SUBJECT

FIG. 1 TAB CARD (Canary) FIG. 2 BOOKS—SUBJECT INDEX (Blue)
FIG. 3 BOOK REVIEWS—SUBJECT INDEX (Manila)

100 numbers. Inasmuch as additions to the original list of titles may be necessary it was not thought advisable to attempt an alphabetical arrangement of the groups. The sizes are designated by letters, A for the smallest, B for the medium, C for the largest, the catalogues for a given title being assigned the same block of numbers for each size and numbered in the order of accession.

9 In a special drawer is a card index or Directory of Manufacturers giving the name, letter size and number of their catalogue, thus facilitating quick selection when only the manufacturers' name is known. Under main titles in the general reference index is placed a special salmon colored card giving the range of numbers and a list of

all the cataloguees of that set with the individual number and letter size. Inspection of this card or the one filed under the manufacturer's name will show if a catalogue is missing from the file.

10 In general the index consists of a series of tab cards on which are printed the names of the various subjects which are connected with Mechanical Engineering. All of these cards are arranged in alphabetical order and are easily found. To make out a consistent list of these subjects has been the chief difficulty of the work of preparing this index but the problem has been satisfactorily solved by having each subject connect in some way with one of the main or subdivisions of Mechanical Engineering.

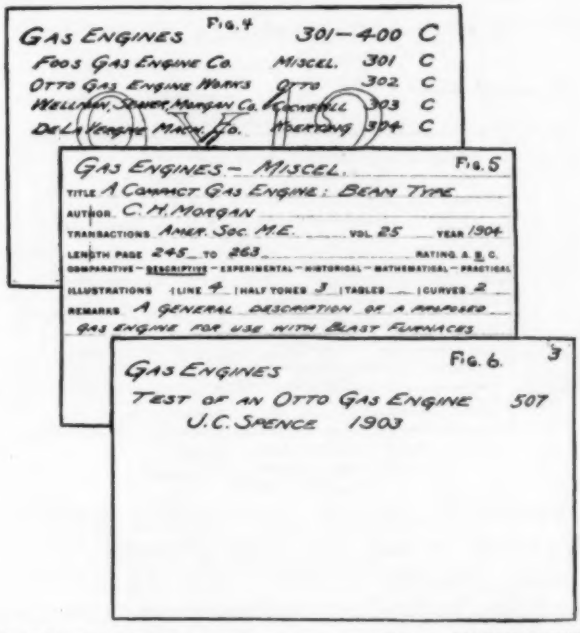
GAS ENGINES Fig. 4 301–400 C
FOOS GAS ENGINE CO. MISCEL. 301 C
OTTO GAS ENGINE WORKS OTTO 302 C
WELLMAN, SEAVER, MORGAN CO. CONCRETE 303 C
DE LA VERGNE MACH. CO. HOISTING 304 C
GAS ENGINES – MISCEL. Fig. 5
TITLE A COMPACT GAS ENGINE: BEAM TYPE
AUTHOR C. M. MORGAN
TRANSACTIONS AMER. SOC. M.E. VOL. 25 YEAR 1904
LENGTH PAGE 245 TO 263 RATING A B C
COMPARATIVE – DESCRIPTIVE – EXPERIMENTAL – HISTORICAL – MATHEMATICAL – PRACTICAL
ILLUSTRATIONS 1 LINE 4 HALF TONES 3 TABLES CURVES 2
REMARKS A GENERAL DESCRIPTION OF A PROPOSED GAS ENGINE FOR USE WITH BLAST FURNACES
GAS ENGINES Fig. 6.
TEST OF AN OTTO GAS ENGINE 507
J.C. SPENCE 1903

FIG. 4 CATALOGUES (Salmon) FIG. 5 TRANSACTIONS (White)
FIG. 6 THESES—STUDENTS (Green)

11 The question naturally arises, What is Mechanical Engineering? and an answer can be found by turning to the tab card Mechanical Engineering. On this card we find:

See also Construction
Machine Design
Materials of Construction
Power
Transportation

Turning to the Power tab card, we find,

See Power Consumption
Power Cost
Power Measurements
Power Plants
Power Transmission

and following out one of these divisions, as, for example, Power Transmission, we find a whole line of topics which are still further subdivided.

12 The tab card may be simply a directory card with the directions for finding the required information, as for example, under Annealing we find, See Heat Treatment, which means that we must turn to Heat Treatment to find out about Annealing.

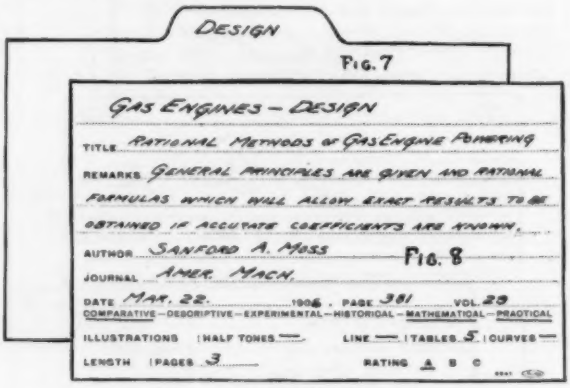
DESIGN
FIG. 7
GAS ENGINES – DESIGN
TITLE RATIONAL METHODS OF GAS ENGINE POWERING
REMARKS GENERAL PRINCIPLES ARE GIVEN AND RATIONAL FORMULAS WHICH WILL ALLOW EXACT RESULTS TO BE OBTAINED IF ACCURATE COEFFICIENTS ARE KNOWN.
AUTHOR SANFORD A. MOSS
FIG. 8
JOURNAL AMER. MACH.
DATE MAR. 22. 1906. PAGE 381 VOL. 29
COMPARATIVE – DESCRIPTIVE – EXPERIMENTAL – HISTORICAL – MATHEMATICAL – PRACTICAL
ILLUSTRATIONS | HALF TONES — LINE — | TABLES 5 | CURVES —
LENGTH | PAGES 3 RATING A B C

FIG. 7 TAB CARD (Canary)
FIG. 8 PERIODICALS (Amber)

13 If, however, the tab card says "See also" then the references are simply suggestive, while back of the tab card itself are the regular index cards. These are of various colors and have the following significance: Blue cards, Books; Salmon cards, Catalogues; Green cards, Theses; White cards, Transactions and Proceedings; Amber cards, Periodicals; and Red cards, Lantern Slides. To illustrate, we turn to Gas Engines, Fig. 1 is the tab card. Back of it we find a blue card, Fig. 2, the numbers at the right refer to envelopes, Fig. 3, which contain the written review and any other information which we may have with regard to the books. The next is a Salmon Card, Fig. 4, with a list of Gas Engine makers. The numbers refer to the catalogues. The 9 x 12 on the card being put there to call attention to the fact that these are the large size catalogues, the letter C being for the same purpose. The next salmon card without the C or 9 x 12

has a list of 6 x 9 catalogues and as this is the prevailing size, no letter is used. The small size is marked 3½ x 6 and A. Fig. 5 is a White Card with a reference to the Transactions of this Society. Fig. 6 is a Green Card with a reference to a thesis on the subject, written by a student of the Institute. The number in this case refers to the thesis, all of which are bound and in the Department Library.

14 We next come to a number of amber cards. Passing these over we come to the middle tab cards, dividing the subject into smaller groups. Fig. 7 shows the one for Design. Back of this we find an amber card, Fig. 8. Fig. 9 shows a blue card used for authors' index in connection with Book Reviews only. Fig. 10 shows a sample of

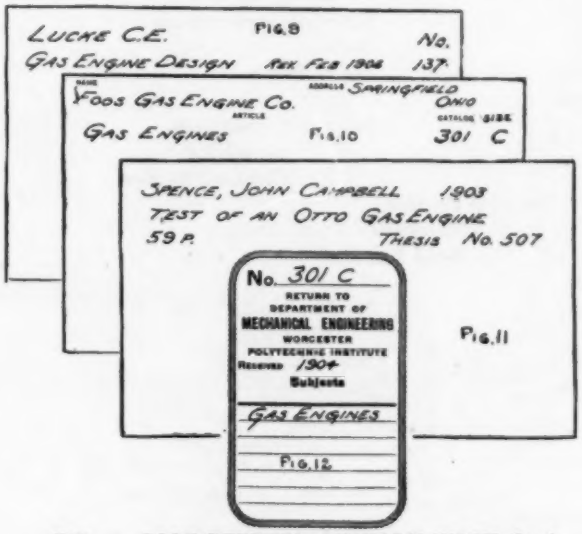

FIG. 9 BOOK REVIEWS—AUTHORS' INDEX (Blue)
FIG. 10 MANUFACTURERS' INDEX (White)
FIG. 11 THESES—GRADUATES (Cream-White)
FIG. 12 CATALOGUE LABELS (White)

the cards as found in the Manufacturers' Directory. Fig. 11, a sample of the cards from the Graduates' Index giving the thesis number of each. Fig. 12 is a sample of the labels used on the catalogues.

15 This file has been in constant use for nearly three years and has proved entirely satisfactory in its operation and maintenance. There are at present on file about 5000 references, about 1000 catalogues and 165 book reviews. The question naturally presents itself: Should a file of this kind be permitted to take on yearly growths without some systematic elimination of the less valuable material? By aiming from the start at select references, it is hoped to restrict this

growth. Aside from this, there seems to be no feasible way of avoiding useless material except to depend on the judgment of the various specialists of the Department who use the index and can easily weed out useless references.

ABRASIVES — See Grinding Materials
ACCELERATION — See Mechanics
ACCUMULATORS — See also Hydraulics
  Pressure Tanks — Intensifiers
  Pumps
ACCIDENTS — See Failures
  Legal Notes
  Insurance—Liability
  Safety Devices
ACCOUNTING — See Shop Management
ACETYLENE — See Gas
ADVERTISING — See Selling
AERONAUTICS
AIR — See also Aeronautics
  Liquid Air
  Thermodynamics
  Flow
  Resistance — See also Friction
  Railroads—Train Resist
  Wind Pressure
AIR BRAKES
AIR MOTORS — See Pneumatic Tools
  Wind Mills
AIR PUMPS — See Pumps—Air
AIR WASHING — See Heating and Ventilation
ALCOHOL — See also Fuels—Tests
  Cost — Liquid Fuels
  Manufacture — Gas Engines—Alcohol
ALLOYS — See also Materials of Const.
  Acid Resistance — Brass
  Manufacture — Bearings—Materials
  Properties — Bronze
  Steel Alloys
  Aluminum—Alloys
  Pattern Metals
  Solder
ALUMINUM
  Alloys — See also Steel Alloys
  Bronze
AMMONIA — See also Refrigeration
ANEMOMETERS — See also Air—Flow
ANNEALING — See Heat Treatment
APPRENTICES
  Education
  Papers
  Miscellaneous Mfg. Plants

ARBOR PRESSES
ARBORS — See Small Tools
ASBESTOS — See Packing
Pipe Coverings
ASPHALT — See Floors
ASSOCIATIONS
Buildings
AUTOMATIC MACHINES — See also Screw Machines—Automatic
AUTOMOBILES — See also Clutches
Cost of Operation — Fire Engines
Design — Traction
Electric — Tires
Gasolene (See also Carburettors) — Wheels
History
Ice
Industrial
Manufacture
Miscellaneous
Patents
Radiators
Regulation
Steam
Testing
Tests
Transmission Gear (See also Variators)
AXLES
BABBITT — See Bearings—Materials
BALANCING — See also Steam Engines—Balancing
Gas Engines
Steam Turbines
BALLS — See also Bearings—Ball
BAND SAWS — See Woodworking Machinery
BEAMS — See also Concrete Construction
Testing — Girders
Tests — Mechanics
BEARINGS — See also Lubrication
Ball — Friction
Design — Gibs
High Pressure — Hangers
High Speed
Knife Edge
Manufacture
Materials for (Alloys) — See also Materials of Construction
Roller
Conical
Tests
Thrust
BELLS
BELT DRESSING

BELT DRIVES — See also Belts
- Compound or Rider — Belt Dressing
- Design — Countershafts
- Quarter Turns — Power Transmission
- Tests—For Strength Tests, see Belts—Tests — Speed Cones
- Testing

BELT LACING MACHINES

BELTS — See also Belt Drives, Belt Dressing
- Cotton
- Fastenings
  - Lacing
  - Splicing
- Leather
- Life of
- Manufacture
- Rubber
- Tests—For Power Tests, see Belt Drives—Tests

BENCHES — See Machine Shops—Equipment, Pattern Shops

BENDING MACHINERY — See also Presses—Benders

BICYCLES

BINARY ENGINES — For Waste Gas Engines, see Gas Engines

BINS

BIOGRAPHY
- Educators
- Engineers
- Inventors
- Manufacturers
- Scientists

BLAST FURNACES — See also Metallurgy
- Design
- Practice

BLOCKS — See Hoists

BLOWERS — See also Blowing Engines, Compressors
- Design
- Exhaust
- Fan
- Manufacture
- Positive
- Testing
- Tests

BLOWING ENGINES — See also Compressors, Blowers

BLUE PRINTING
- Apparatus
- Positive Process
- Receipts

BOILERS — See also Heat—
- Circulation — Insurance

Construction
Cost of Operation
Design See also Rivets
Riveted Joints
Bracing
Stay-bolts
Explosions See also Explosions
Feed
Automatic
Flash
Flues
Furnaces See also Combustion
Flue Gases
Furnaces—Smokeless
Grates
Pyrometers
Stokers
Incrustation See also Water—Purification
Locomotive See also Locomotives
Marine See also Marine Engineering
Design
Fire Tube
Water Tube
Manufacture
Oil effect
Operation
Portable
Safety Devices See also Safety Valves
Fusible Plugs
Testing See also Flue Gases
Calorimeters
Tests
Theory
Water Tube
Pipe Coverings
Power Plants
Radiation
Tube Cleaners
Tubes
Valves
Water Columns

BOILER COMPOUNDS
BOLT CUTTERS
BOLTS and NUTS See also Fastenings
Hardware
Design
Manuacture
Tables
Tests
BOOK REVIEWS See Blue Cards under main titles
Book Reviews are numbered consecutively in the Book Review Drawer
Authors names are given in the Directory Drawer
BOOKS See also Hand Books
BORING BARS

BORING MACHINES
BORING MILLS — See also Machine Tools
  Design
  Tests — See also Power Consumption
BOXES — See Bearings
BOXING — See Shipping
BRAKES — See also Air Brakes
  Automatic — Cranes—Brakes
  Band — Dynamometers—Absorption
  Design
  Electric
  Tests
BRASS (COPPER ZINC ALLOYS) — See also Materials of Construction
  Tests — Extruded Metal
BRASS FOUNDRY
  Equipment — See also Furnaces
    Crucibles
  Practice
  Miscellaneous Plants
BRAZING — See also Solder
BREAKERS — See Foundry Equipment
    Mining Machinery
BRICK — See also Fire Brick
    Foundations
    Mill Construction
BRIDGES
  Draw
BRIDGE PLANTS
  Equipment
  Miscellaneous
BROACHES — See Small Tools—Broaches
BRONZE — See also Materials of Construction
  Aluminum — See also Aluminum—Alloys
  Gun Metal
  Manganese
  Phosphor
  Tests
  Tobin
BRUSHES
BUCKETS — See Coal Handling Machinery
    Water Turbines
    Water Wheels
BUFFERS — See also Dash Pots
BULLDOZERS — See also Forge Practice
    Forge Shops
BUNKERS — See also Coal Handling Machinery
    Power Plants
    Coal-Storage

BURNERS — See also Liquid Fuels; Furnaces—Oil; Locomotives—Oil Burning

CABLES — See Chain; Rope; Wire Rope

CABLEWAYS

CALIPERS — See Machinist's Tools

CALORIMETERS
- Coal
- Gas
- Steam

CAMS — See also Mechanism
- Design
- Manufacture
- Tests

CANALS
- Locks

CANNON — See Guns

CARBON — See Cast Iron—Chemistry; Steel Making—Chemistry

CARBORUNDUM — See Grinding Materials

CARBURETTORS — See also Automobiles—Gasolene; Gas Engines

CARS
- Dump
- Fire Proof
- Steel
- Tank

CAR WHEELS — See Wheels—Car

CASE HARDENING — See also Heat Treatment
- Cast Iron
- Supplies

CAST STEEL — See Steel Castings; Steel Making—Crucible; Tool Steel

CASTERS

CASTINGS — See Bronze, Cast Iron, Brass; Die Castings; Foundry Practice; Malleable Castings; Steel Castings

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Pipe—Tools
WROUGHT IRON See also Corrosion
Crystallization Materials of Construction
Tests Metallography
YIELD POINT See Materials of Construction—Tests
ZINC See also Alloys
Brass
Materials of Construction

THE FLOW OF FLUIDS IN A VENTURI TUBE

By EDGAR PARK COLEMAN, BUFFALO, NEW YORK
Member of the Society

1 Converging and diverging tubes and combinations of the same, with many of their properties, have been well known for many years. The diverging tube was investigated by Bernouilli in 1738. Venturi in 1791 experimented with the compound tube which now bears his name. The object of these investigations was to determine the coefficients of discharge for these tubes when used as nozzles for the discharge of water from a reservoir. In 1887 Herschel published the results of his experiments, showing that the Venturi tube is an accurate meter for measuring the quantity of liquid flowing through it.

2 While the use of the Venturi tube for the measurement of liquids is quite general, its application to the measurement of gases does not seem to be well known, or at least is not practiced by many engineers. That the Venturi tube is an instrument of convenience and precision when used for measuring the quantity of air or gas (and in some cases of steam) flowing through it, the writer will show by the results of experiments.

3 The volume of fluid passing any cross-section of a pipe or tube per unit of time is equal to the product of the area of the section and the velocity of the fluid. Since the velocity is not usually directly observable, it became necessary to determine the relations existing between areas, velocities, pressures, and densities, from which the velocity at the throat may be calculated when the other quantities are known.

4 About the middle of the eighteenth century, Bernouilli discovered the law, since known as Bernouilli's theorem, governing the steady flow of liquids in a pipe. This law is a statement of the fact that for any pipe of whatever varying cross-sectional area, through which the liquid has attained a steady flow; considering any point in the length of the pipe, the sum of pressure head, velocity head, fric-

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tion head lost up to that point, and height above datum, is equal to a constant. Stated mathematically, the law becomes:

$$P_1 + \frac{v_1^2}{2g} + F_1 + h_1 = P_2 + \frac{v_2^2}{2g} + F_2 + h_2 = \text{Constant} \qquad [1]$$

5 For short lengths and low velocities, the loss of head by friction becomes negligible, and if in addition we assume a horizontal pipe, or in the case of a non-horizontal pipe, if the difference in pressure between the two points be measured by means of a U column, the term "height above datum" disappears and the expression becomes,

$$P_1 + \frac{v_1^2}{2g} = P_2 + \frac{v_2^2}{2g} = \text{Constant} \qquad [2]$$

The velocity must vary inversely as the area; that is, $v_1 = \frac{A_2}{A_1} v_2$, and by substituting this value in equation [2], and solving for v_2, the formula for the Venturi water meter becomes:

$$v_2 = \frac{A_1}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gh} \qquad [3]$$

as developed by Merriman, and proven by the experiments of Herschel; where A_1 and A_2 are the respective areas of up-stream and throat cross-sections in square feet, v_2 is the velocity at the throat in

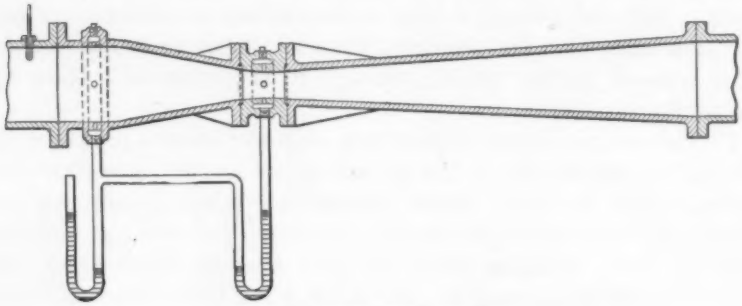


FIG. 1 VENTURI TUBE

feet per second, and h is the difference in pressure due to change of velocity, between the up-stream and throat sections, expressed in feet of the liquid. Herschel's experiments with water show this expression subject to a coefficient to correct for friction losses. This coefficient has an average value of .972, being greater for low and smaller for high throat velocities.

6 For measuring water it is desirable that the throat area be such that the throat velocityshall be between the limits of 15 and 35 feet per second. It frequently happens that the amount of water to be meas-

ured varies greatly from minute to minute. In such cases, greater accuracy is secured by taking the square root of h for each observation separately, and then averaging. We thus obtain the average square root of h which is desired, rather than the square root of the average h. It is also important to remember the correction for the water column, if a mercury U column, as is usual, is connected in differential between up-stream and throat. Thus if:

H = deflection of mercury column in inches;
h = pressure difference in feet of water;
13.59 = sp. g. of mercury;

$$\text{Then } h = \frac{(13.59\text{-}1)\ H}{12} \qquad [4]$$

7 In the preceding, it is of course assumed that the integrating register is not available, which if in use performs all of the above mentioned steps automatically.

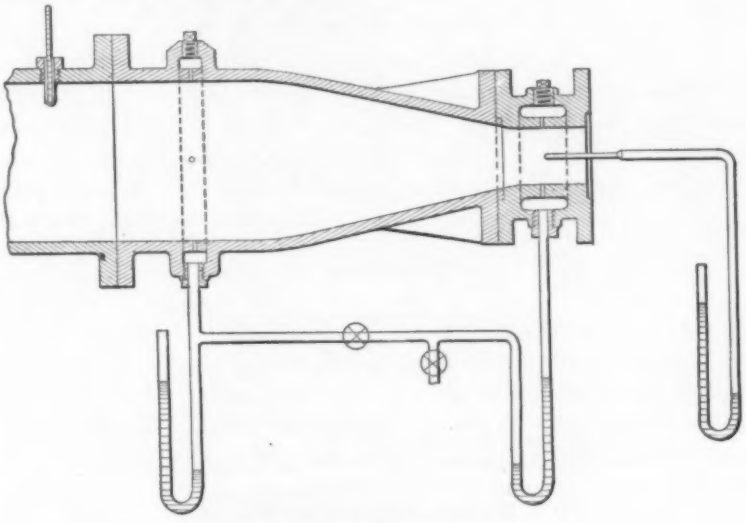


FIG. 2 CONVERGING NOZZLE

8 The flow of steam and air through nozzles and orifices has been investigated by Zeuner, Hirn, Peabody, Rateau, and others. The general formula governing the flow is ascribed to Wantzel and St. Venant in 1839, and is:

$$\frac{v^2}{2g} = \int_p^P v\,dp \qquad [5]$$

which can be integrated when the relations between volume and pressure are known.

9 Bernouilli's law, equation [1], governing the flow of liquids in a pipe evidently will not hold in the case of gases or vapors, where temperature and density are intimately related with change of pressure. Apparently, a general law governing the steady flow of any fluid in a pipe is:

10 Considering any point in the length of the pipe, the sum of potential energy, kinetic energy, and energy otherwise lost up to that point (all per unit mass of the fluid) is equal to a constant. This applies to any pipe of whatever varying cross-section, as in this case to a converging nozzle, or to a Venturi tube. Neglecting friction, radia-

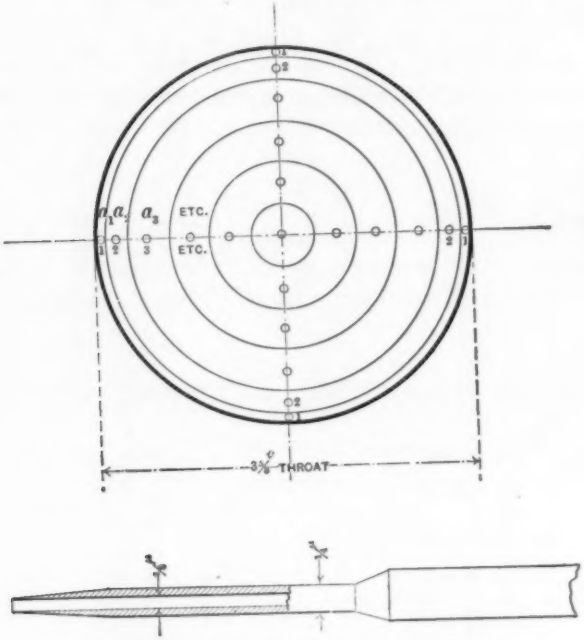


FIG. 3 THROAT CIRCLE AND PITOT TUBE

tion or other abstraction of heat or its equivalent, we may say that the total energy per unit mass of fluid is constant. Obviously this last will apply without material error within a limited range of lengths or velocities or both. It may be noticed in passing that when utilizing the Venturi tube as a meter we are concerned with the up-stream and throat parts only, which taken together form a converging nozzle, the sole function of the diverging down-stream part being to transform the major portion of the increased kinetic energy at the throat back again into pressure energy at the down-stream end, thus

reducing the pressure drop through the meter. The same formulæ, therefore, apply to Venturi tubes or to converging nozzles.

FLOW OF GAS IN A VENTURI TUBE

In the notation:
Subscript 1 refers to the up-stream section,
Subscript 2 refers to the throat section,
Subscript 3 refers to the down-stream section.
A = area in square feet;
P = pressure in pounds per sq. ft. absolute;
v = velocity in ft. per second;
C = volume of one pound of gas in cu. ft.;
r = density of gas = $\frac{1}{C}$

$$K = \frac{\text{sp. h. at constant pressure}}{\text{sp. h. at constant volume.}}$$

11 Referring to Fig. 1, gas flowing steadily from A_1 to A_2, will change in pressure, velocity, volume, density and temperature respectively from P_1 to P_2, v_1 to v_2, etc. Assuming the total energy per pound of gas as constant, we may write:
Decrement of Potential Energy = Increment of Kinetic Energy. [6]
Assuming adiabatic expansion,

$$P\,C^K = P_1\,C_1^K = P_2\,C_2^K \qquad [7]$$

12 The work diagram, *abcea*, Fig. 4, representing the change in pressure energy per pound of gas, while passing from the up-stream to the throat section, resembles in form the indicator card from a compressed air engine having zero clearance. The work performed by the gas through its expansion consists in changing its own velocity from v_1 to v_2, and is numerically equal to the area *abcea*. Bounded areas being understood:

$$abcea = abfoa + bcdfb - oecdo$$
$$abfoa = P_1\,C_1$$
$$oecdo = P_2\,C_2$$

$$bcdfb = \int_{C_1}^{C_2} P\,dc = P_1\,C_1^K \int_{C_1}^{C_2} \frac{dc}{C^K}$$
$$= \frac{P_1\,C_1}{1-K}\; C^{1-K}\Big]_{C_1}^{C_2} = \frac{P_1\,C_1 - P_2\,C_2}{K-1}$$

Hence,

$$abcea = P_1 C_1 + \frac{P_1 C_1 - P_2 C_2}{K-1} - P_2 C_2 ,$$

and since $P_2 C_2 = P_1 C_1 \left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}}$, and $C_1 = \frac{1}{\Gamma_1}$,

$$abcea = \frac{K}{K-1} \frac{P_1}{\Gamma_1} \left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}} \right] \qquad [8]$$

13 The change in kinetic energy per pound of gas is numerically equal to $\frac{v_2^2 - v_1^2}{2g}$. Hence—

$$\frac{v_2^2 - v_1^2}{2g} = \frac{K}{K-1} \frac{P_1}{\Gamma_1} \left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}} \right] \qquad [9]$$

Since $A_1 v_1 \Gamma_1 = A_2 v_2 \Gamma_2 = Q$,

$$v_1 = v_2 \frac{A_2}{A_1} \frac{\Gamma_2}{\Gamma_1} = v_2 \frac{A_2}{A_1} \left(\frac{P_2}{P_1}\right)^{\frac{1}{K}}$$

Substituting this value in equation [9] and solving for v_2, we get—

$$v_2 = \left(\frac{P_1}{\Gamma_1}\right)^{\frac{1}{2}} \left(\frac{2\,g\,K}{K-1}\right)^{\frac{1}{2}} \left\{ \frac{1 - \left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}}}{1 - \left(\frac{A_2}{A_1}\right)^2 \left(\frac{P_2}{P_1}\right)^{\frac{2}{K}}} \right\}^{\frac{1}{2}} \qquad [10]$$

The weight of gas in pounds per second is

$$Q = A_2 v_2 \Gamma_2 = A_2 v_2 \Gamma_1 \left(\frac{P_2}{P_1}\right)^{\frac{1}{K}}$$

$$= (P_1 \Gamma_1)^{\frac{1}{2}} A_2 \left(\frac{2\,g\,K}{K-1}\right)^{\frac{1}{2}} \left(\frac{P_2}{P_1}\right)^{\frac{1}{K}} \left\{ \frac{1 - \left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}}}{1 - \left(\frac{A_2}{A_1}\right)^2 \left(\frac{P_2}{P_1}\right)^{\frac{2}{K}}} \right\}^{\frac{1}{2}} \qquad [11]$$

$$= (P_1 \Gamma_1)^{\frac{1}{2}} M f\left(\frac{P_2}{P_1}\right) \qquad [12]$$

Where M is the constant involving any given throat area and ratio of specific heats, and $f\left(\frac{P_2}{P_1}\right)$ is the quantity in equation [11] which

involves the ratios of pressures, areas and specific heats. It will be found convenient to plot $Mf\left(\frac{P_2}{P_1}\right)$ against the ratio of pressures, thus avoiding tedious calculations in practice. The locus of this quantity is shown in part in Fig. 5, for a tube involving a throat area of .07167 square feet, an area ratio of .13141, and a value of $K = 1.408$. In solving any concrete example then, knowing the values of P_1, $\frac{P_2}{P_1}$, and r_1 from observation, we obtain the corresponding value of $Mf\left(\frac{P_2}{P_1}\right)$ from the curve, substitute the necessary values in equation [12], and solve for Q. In a similar manner from equation [10] we obtain

$$v_2 = \left(\frac{P_1}{r_2}\right)^{\frac{1}{2}} M^1 f^1 \left(\frac{P_2}{P_1}\right) \qquad [13]$$

which is also plotted in Fig. 5. This curve is useful in determining the throat area required to measure a given amount of gas, under conditions given or assumed. For air (or gas of approximately the same

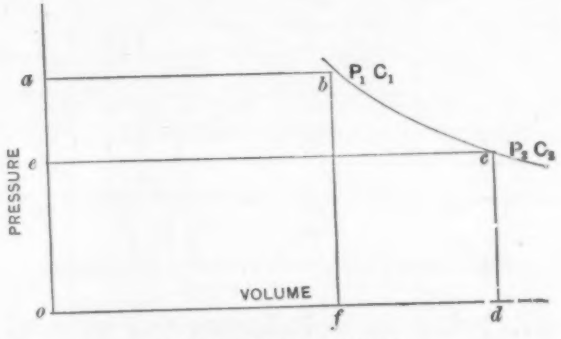


FIG. 4 WORK DIAGRAM

density), at or near a pressure of one atmosphere, desirable values of the ratio of P_2 to P_1 are between the limits of .95 to .995, corresponding to throat velocities of 100 to 300 feet per second. At higher pressure the throat velocity may be higher. In general the limiting value of the lower velocity depends on the least manometer reading which can be observed with sufficient accuracy, while the maximum allowable velocity will usually be determined by the allowable drop in pressure due to the meter.

14 By making $v_1 = 0$ in equation [9], or $A_1 = \infty$ in equation [10], we obtain the expression for velocity under the condition of adiabatic flow through an orifice in a thin plate. Similarly, if $A_1 = \infty$ in equation [11], we have the expression for rate of discharge under the same conditions (an experimentally obtained coefficient of discharge being, of course, assumed).

15 When conducting some tests in 1903 of boilers using blast furnace gas for fuel, the writer was obliged to accept on faith the results from this method of measuring the gas. Later, in order to test its action with steam, a six-inch Venturi was placed in the steam line leading to the yards about a group of furnaces, boilers were isolated to supply the steam, the feed water was weighed, and observations were made at the meter by means of gages and mercury column. Sub-

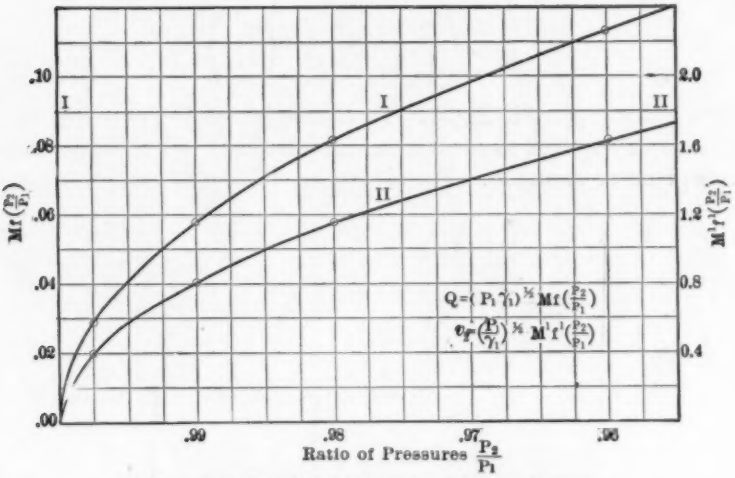


FIG. 5 COMPUTATION CURVES FOR 10" METER

sequently a six-inch and a ten-inch meter were connected to an air supply maintained at about nine ounces pressure above the atmosphere, and the results compared with those simultaneously obtained by inserting a Pitot tube in the throat of the meter. While the experiments were limited in number, and do not include a sufficient range of velocity, it is believed that they prove at least commercial accuracy.

16 In the experiments involving steam measurements, the steam was known to be about 99.5 per cent dry. The absolute pressure was about 110 pounds per square inch and the value of K was assumed to be 1.135. Two experiments were made, one at a throat velocity of 572 and one at 208 feet per second. The respective errors based on

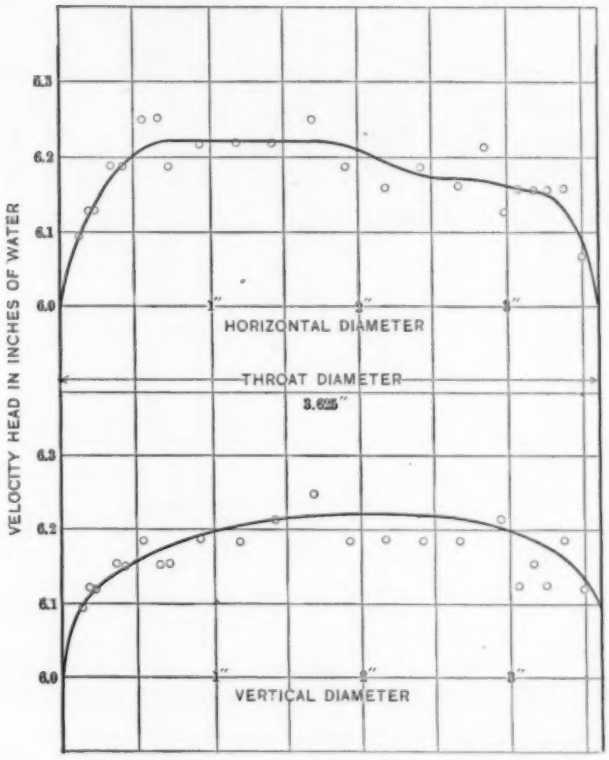


FIG. 6 PITOT TUBE READINGS IN THROAT OF 10" VENTURI TUBE

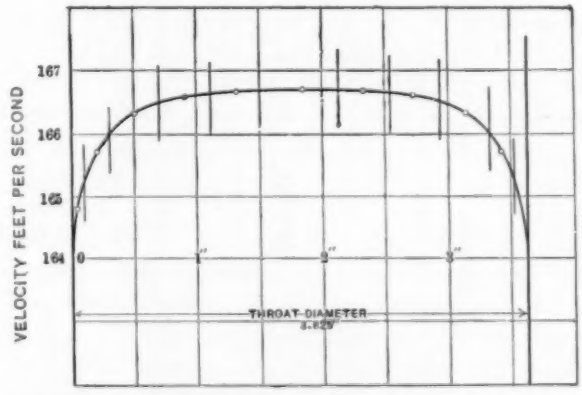


FIG. 7 AVERAGE VELOCITY DIAGRAM IN THROAT OF 10" VENTURI TUBE

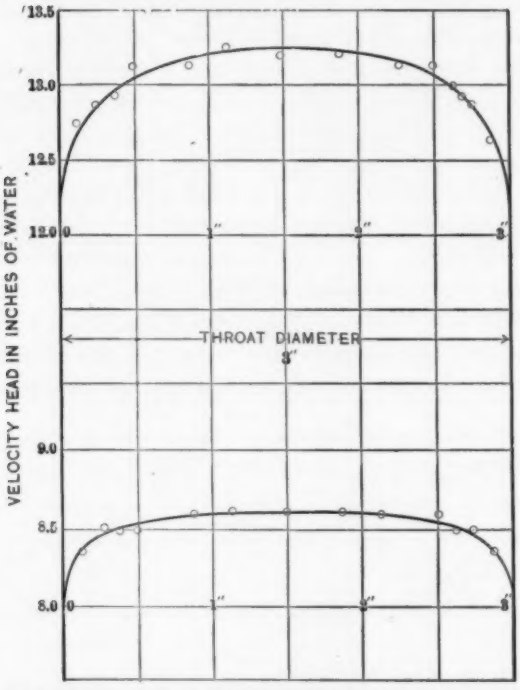


FIG. 8 PITOT TUBE READINGS IN THROAT OF 6" VENTURI TUBE

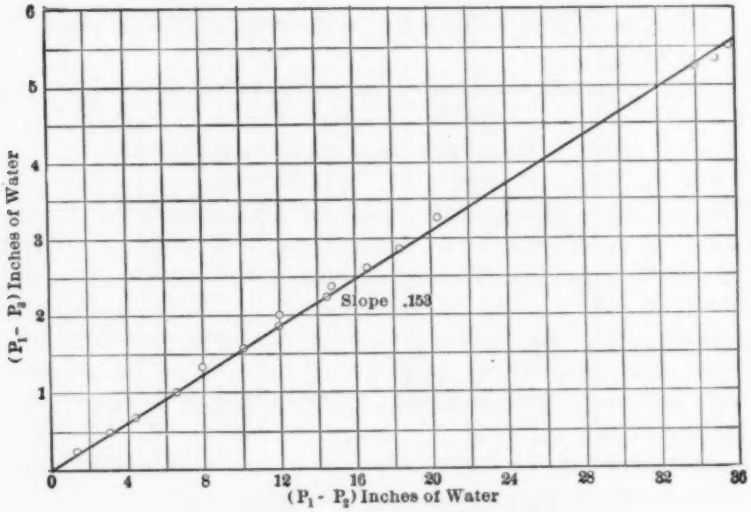


FIG. 9 PRESSURE LOSS IN 6" VENTURI TUBE

feed water weighed were + .056 and −.84 per cent. The data from these tests are as follows:

Item	*Test No. 1*	*Test No. 2*
Date, 1904	Oct. 21	Oct. 22
P_1 lbs. per sq. ft.	15,666	15,934
P_2 lbs. per sq. ft.	14,470	15,775
$\frac{P_2}{P_1}$	.9236	.990
A_2 sq. ft.	.02182	.02182
A_1 sq. ft.	.19635	.19635
Barometer	28.73	29.23
K	1.135	1.135
Q lbs. per sec. by meter	2.851	1.1015
W lbs. per sec. by weight	2.8494	1.1108
$\frac{Q}{W}$	1.0006	.9916
γ_1 lbs. per cu. ft.	.2457	.2498
$P_1 - P_2$ lbs. per sq. in.	8.3	1.2
$P_1 - P_3$ lbs per. sq. in.	4.6	.4
v_2 ft. per sec.	572	208

17 While the above results indicate accuracy of the meter operating under the conditions mentioned, it is believed that with steam containing more than a small percentage of entrained moisture, that the results will be uncertain, owing to the change in the value of K accompanying the increased wetness of the steam. This belief was strengthened by the fact that a Venturi meter placed in the steam line which supplied two large simple duplex pumps, showed erratic results; that is to say, the steam apparently used per horse power hour varied greatly from day to day, even though the speed and condition of the pump remained the same. The steam was known to be very wet, and the arrangement of the piping made thorough drainage impossible. The attempt to measure the steam in this manner was therefore abandoned.

18 Referring to the experiments with air, the supply was taken through a six-inch pipe and discharged through the tube to the atmosphere. In the case of the six-inch meter, Pitot readings were taken along the vertical axis only, but when calibrating the ten-inch meter, Pitot readings were taken along both vertical and horizontal diameters of the throat circle, on account of a slight distortion of the stream lines due to ells in the up-stream piping.

19 Fig. 1 is a diagram of the ten-inch tube complete. Fig. 2 shows the same with the down-stream portion removed, the Pitot tube inserted into the throat, and the water columns connected. Fig. 3 shows a detail of the Pitot tube and the method used in obtaining the average velocity from the Pitometer readings, *i. e.*:

$$v_2 = \frac{\Sigma\ av}{\Sigma\ a}$$

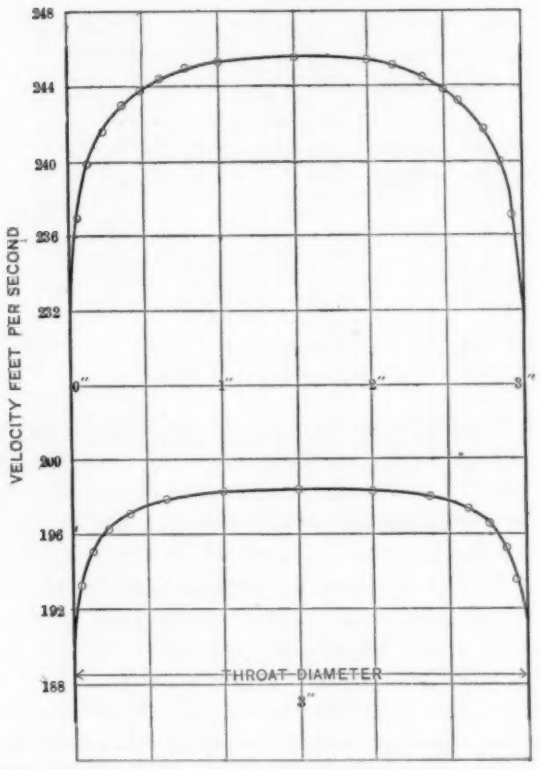


FIG. 10 AVERAGE VELOCITY DIAGRAM IN THROAT OF 6" VENTURI TUBE

Fig. 6 is a diagram of the velocity heads obtained by Pitot observations in the throat of the ten-inch tube when the pressure difference, $(P_1 - P_2)$, was kept constant at six inches of water column. The velocity heads (1, 1, 1, 1, etc.) were averged in fours, and from these averages was derived the average velocity diagram, Fig. 7, from which was computed the average velocity in the throat by the method mentioned above. The data and results for this test are as follows:

Test Number	3
Date, 1905	Nov. 9
Air temperature, degs. F.	60.5
Barometer, ins. Hg.	29.25
P_1 ins. of water	5.0625
P_2 ins. of water	−0.9375
$P_1 - P_2$ ins. of water	6.0
$\frac{P_2}{P_1}$	.98511
A_2 sq. ft.	.07167
A_1 sq. ft.	.5454
K	1.408
γ_1 lbs. per cu. ft.	.07552
γ_2 lbs. per cu. ft.	.074715
Q lbs. per sec. by Venturi	.88289
W lbs. per sec. by Pitometer	.88986
v_2 ft. per sec. by Pitometer	166.2
Q/W	.9922

20 Other observations taken along one diameter only of the ten-inch meter gave results as follows:

Test Number	v_2	Q/W
4	193.5	1.0017
5	193.5	.9916
6	191.6	.9970
Average	192.9	.9963

21 With the six-inch meter, Pitot observations were made along one diameter of the throat circle. Two experiments were made, the data and results from which are shown in the following table:

Test Number	1	2
Date, 1905	June 27	June 27
Air temperature	75.	75.
Barometer	29.47	29.47
P_1 ins. of water	9.0	6.0
P_2 ins. of water	−3.0	−2.0
$P_1 - P_2$ ins. of water	12.0	8.0
$\frac{P_2}{P_1}$	.97042	.98031
A_2	.04909	.04909
A_1	.19636	.19636
K	1.408	1.408

r_1	.07473	.07418
r_2	.07315	.07314
Q	.86745	.70623
W	.86962	.70792
v_2	242.2	197.16
Q/W	.9975	.9976

22 The observed velocity heads and the velocity diagrams for these tests are shown in Figs. 8 and 10, respectively. Fig. 9 shows the pressure loss in the six-inch tube plotted against the increase of velocity head due to decrease in section. It is seen to be in this case 15.3 per cent of the said increase in velocity head. For a 16-inch tube having a 6¼ inch throat, it was found to be 23.8 per cent.

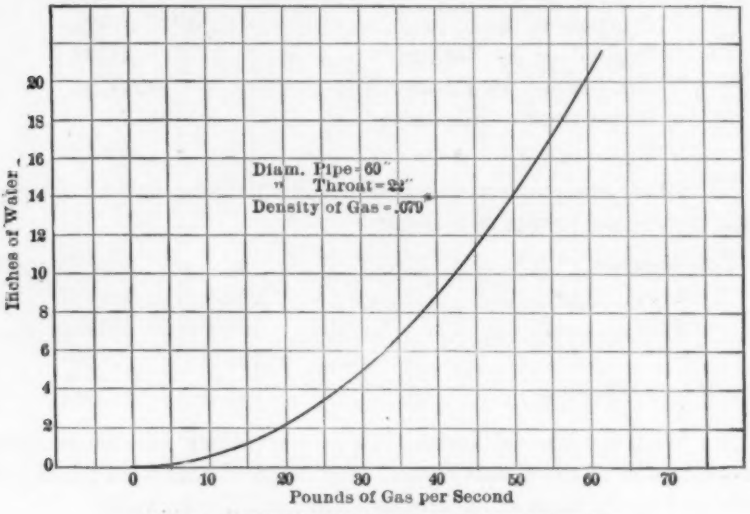


FIG. 11 COMPUTATION CURVE FOR 60" METER

23 Fig. 11 shows the quantity Q in pounds per second plotted against $P_1 - P_2$ in inches of water, for blast furnace gas of constant initial pressure, temperature and density, flowing through a five-foot meter, having a 22 inch throat. As the gas is usually held at a constant pressure above atmosphere, results based on this type of curve will be subject to errors due to variation of the barometer.

24 It is found that with blast furnace gas (and presumably with producer gas), a deposit adheres to the throat and other parts of the meter after continued use. This deposit if not removed affects the accuracy in two ways; first, by decreasing the area of the throat, and, second, by closing or distorting the small holes leading to the

pressure chambers. This may be obviated in several more or less convenient ways.

25 The tests herein described (especially those with steam) do not cover a sufficient range of conditions to be conclusive in every way. While the method used for obtaining the throat pressures would be objectionable at very high velocities, the error here is negligible. With better facilities, and to determine completely the limitations of the Venturi as a measuring device, further experiments should be made covering a more complete range of conditions for both gases and vapors.

TESTS OF A PLUNGER ELEVATOR PLANT

By ARTHUR J. HERSCHMANN, NEW YORK, N. Y.
Member of the Society

1 The tests to which the appended tables refer are commerical tests made on the plunger elevator plant of the Trinity Building, New York City, while in regular operation. It was not thought that the accuracy of the results would be materially improved by resorting to greater elaboration in preparing for the test, or in the manner of conducting same. On the other hand, it was held that with the plan adopted data would be obtained which would enable the plant to be readily compared with those of other buildings while in regular operation and such data should, on account of the peculiarity of elevator service in an office building, more correctly define actual economy than the results obtained from a dead load test in which intermittency of service would not be the same as in the ordinary running of an elevator plant.

2 It will be seen that two series of tests are tabulated. In the first, September 7, a duplex compound pump was used, and in the second, September 8, a high duty fly wheel pump.

3 With the use of the auxiliary steam line it was possible to run the elevator pump on a separate boiler of 350 horse-power, steam for the remainder of the plant as well as for all boiler feeding being supplied each day by a boiler of 265 horse power.

4 It should be noted that, roughly speaking, boilers and pumps were run at about half load so that with a heavier traffic the economy should be further improved.

5 The five high rise elevators discharge into auxiliary tanks from which water is supplied to the cylinder through an automatic valve when the pressure water is shut off on the up trip. This system saves about 5 per cent of the plunger displacement in high pressure water.

6 Approximate figures are given for the water evaporated by the boilers but any error in these figures does not affect the results obtained for the economy, which are based on the amount of coal burned. The water was measured by a meter which was not calibrated during

To be presented at the New York Meeting (December, 1906) of The American Society of Mechanical Engineers, and to form part of Volume 28 of the Transactions.

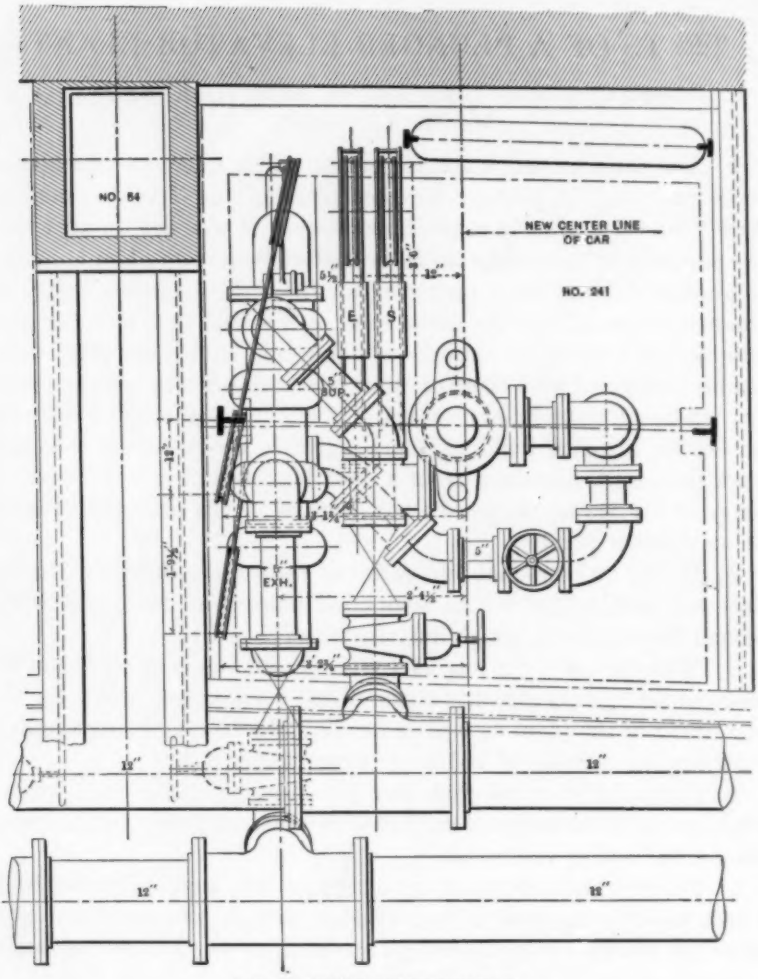


FIG. 1 PLAN OF ELEVATOR

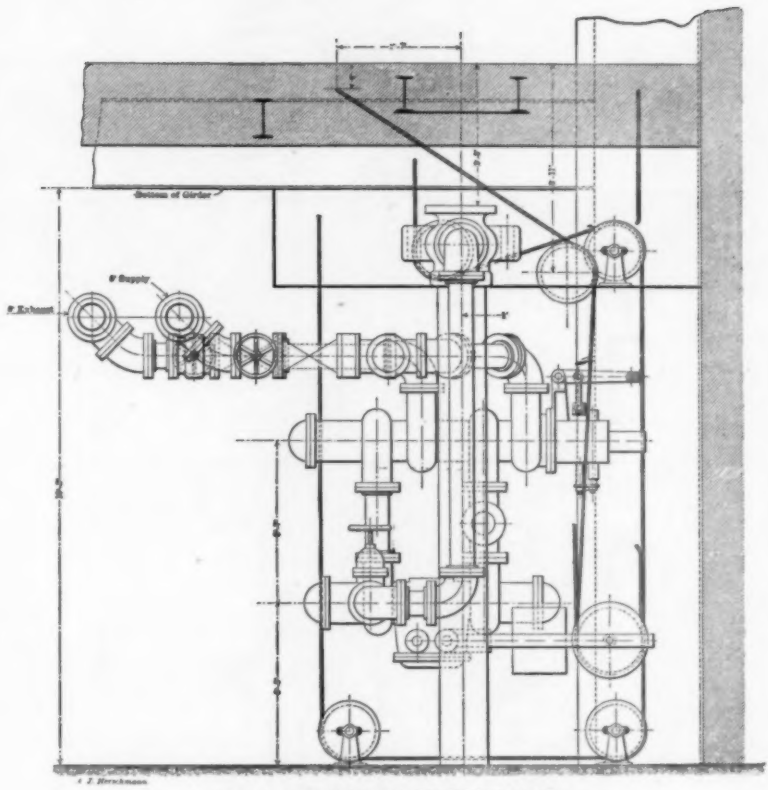


FIG. 2 ELEVATION OF ELEVATORS

or after the tests. The meter was, however, calibrated by the maker before the tests and found to be substantially correct, so that it is believed that the figures for evaporation cannot be very much in error. All figures depending on the reading of the meter are marked "approximate" in the tables.

7 It will be seen that the cost of coal per car mile was 5.22 cents with the fly wheel pump, and 8.04 cents with the compound duplex pump.

8 Costs are figured for the service referred to, including necessary losses, such as leakage, slip, and water consumed by pilots and motor valves.

9 Thanks are due to Mr. F. E. Glass and Mr. Noble C. Butler, Jr., who have assisted me in conducting above tests, also to Chief Engineer Thure Larssen of the Plunger Elevator Company for drawings and data supplied for publication before the Society.

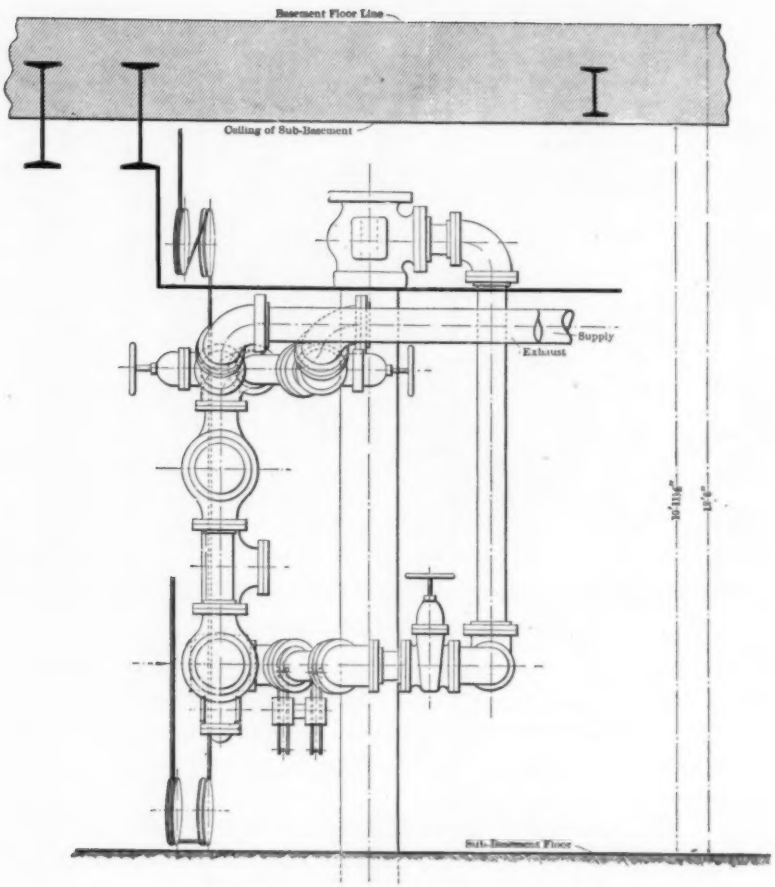
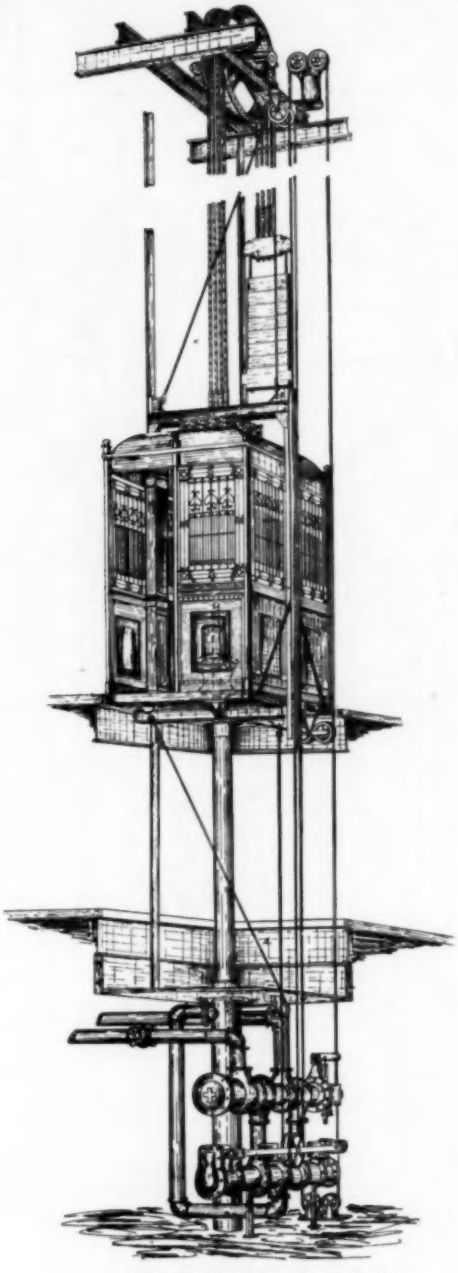


FIG. 3. ELEVATION OF OPERATING VALVES



STANDARD PLUNGER ELEVATOR CO.,
WORCESTER, MASS.
FIG. 4

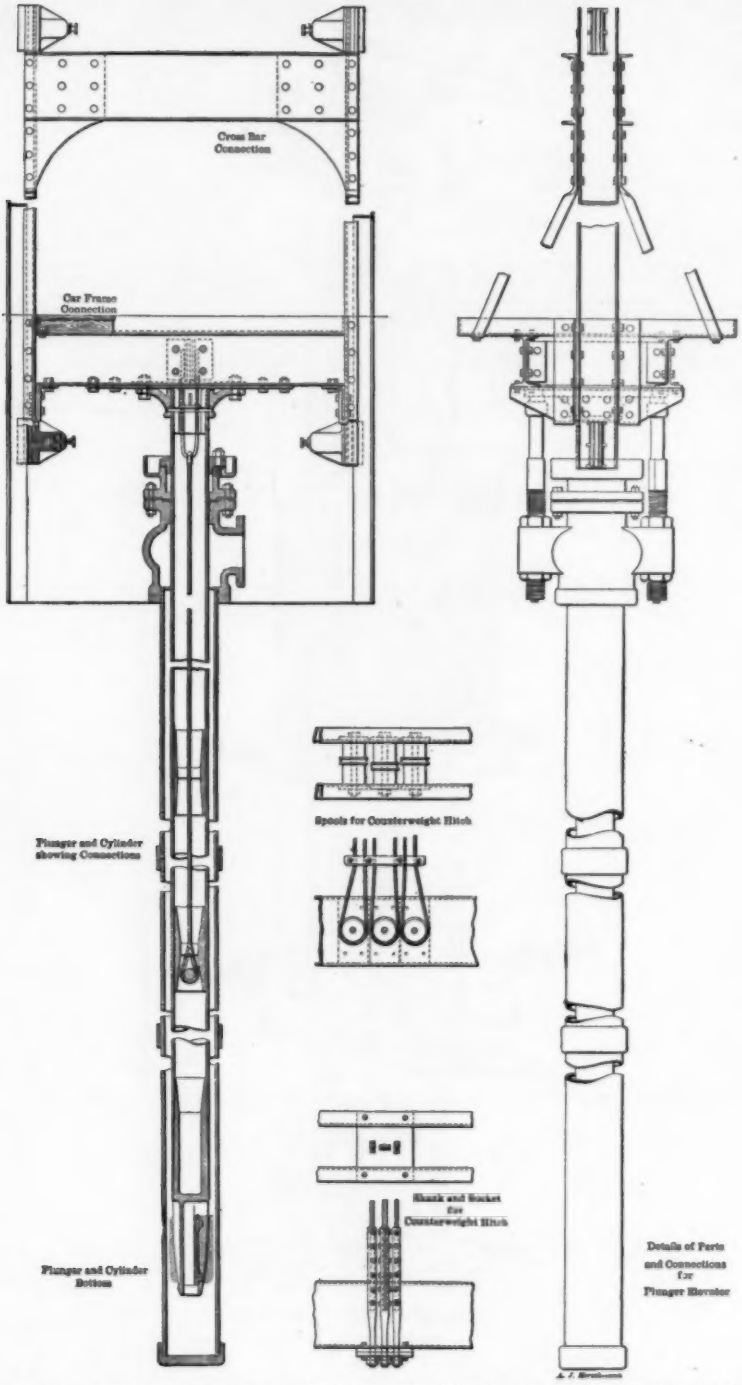

Cross Bar Connection
Car Frame Connection
Plunger and Cylinder showing Connections
Spools for Counterweight Hitch
Shank and Socket for Counterweight Hitch
Plunger and Cylinder Bottom
Details of Parts and Connections for Plunger Elevator

FIG. 5 DETAILS OF PARTS AND CONNECTIONS FOR PLUNGER ELEVATOR

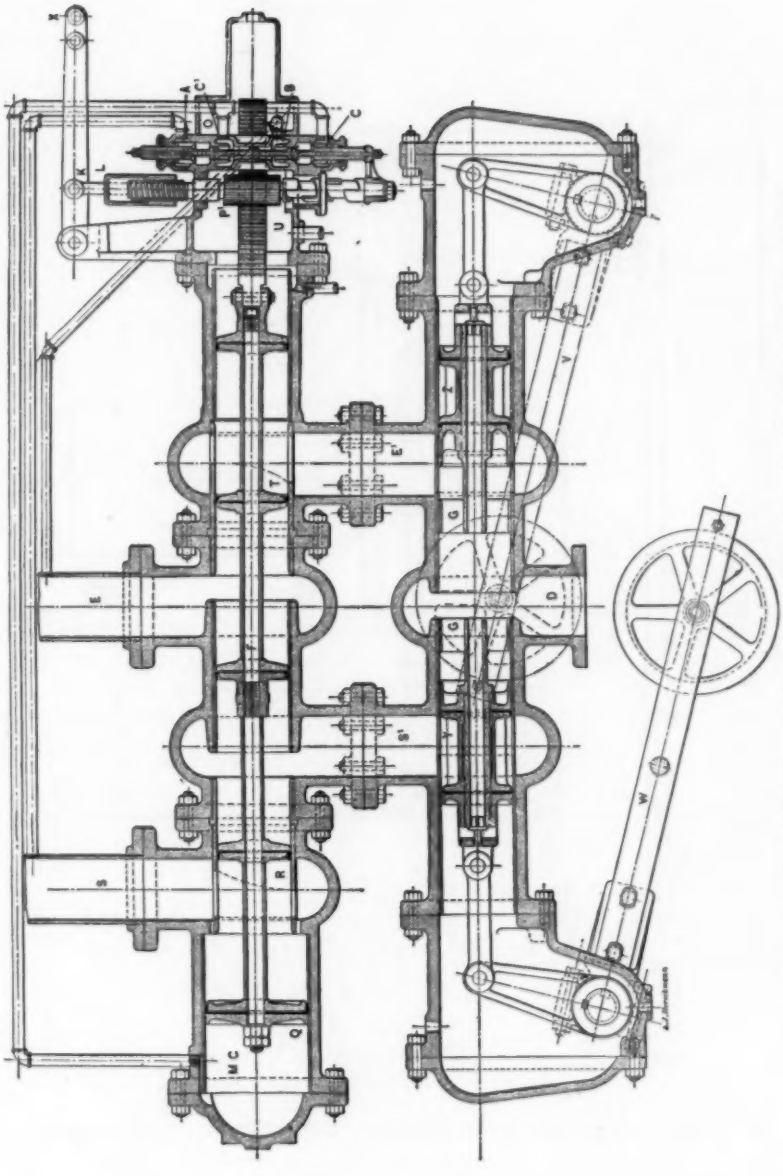


FIG. 6. PILOT CONTROLLING VALVE AND TERMINAL AUTOMATIC STOP VALVE.

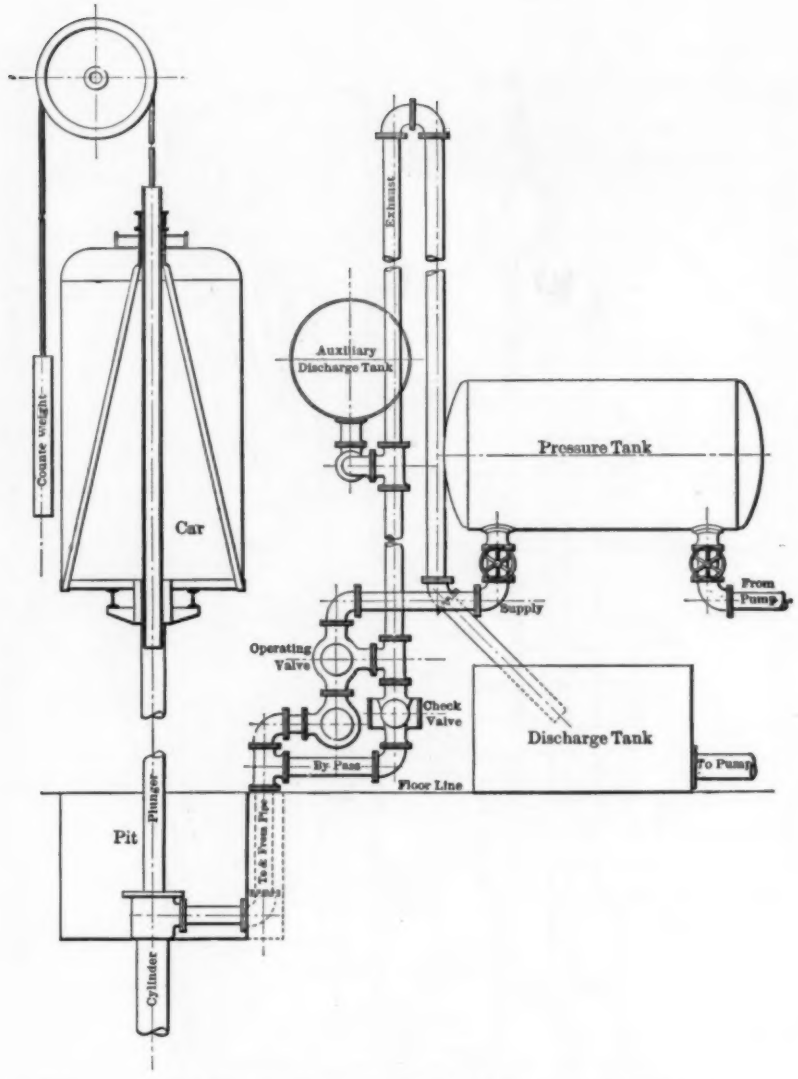


FIG. 7 TYPICAL PIPING DIAGRAM SHOWING BACK PRESSURE SYSTEM.

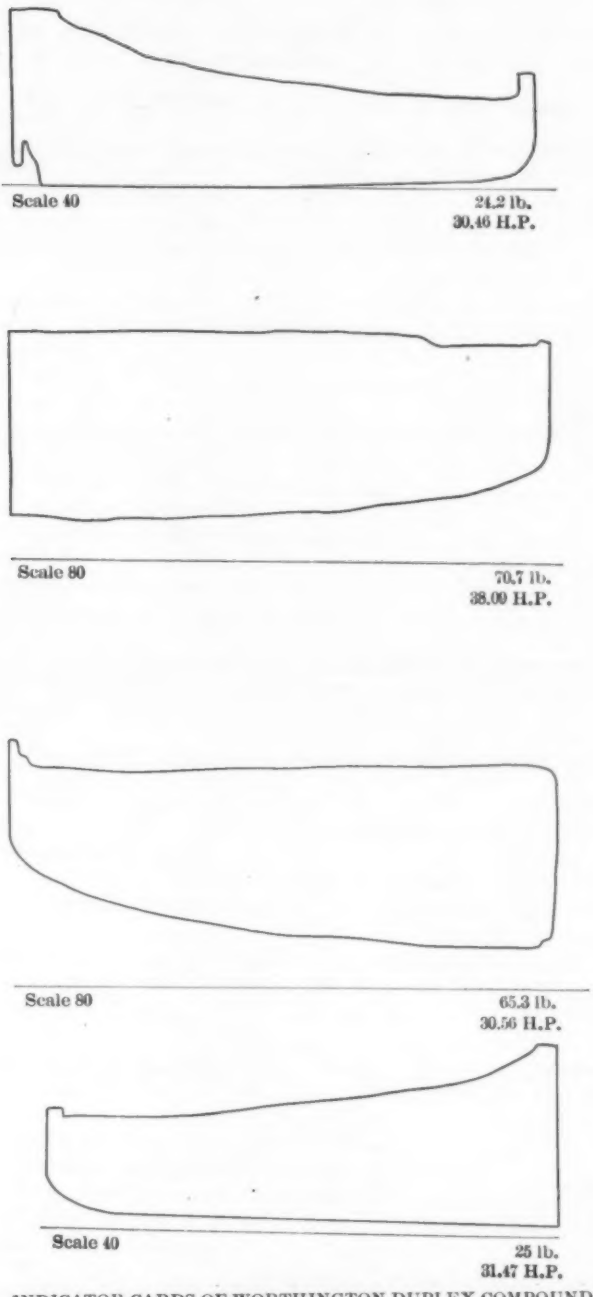
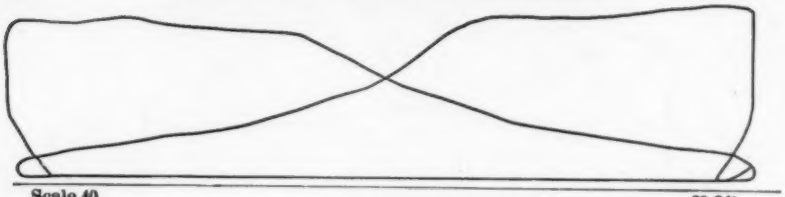
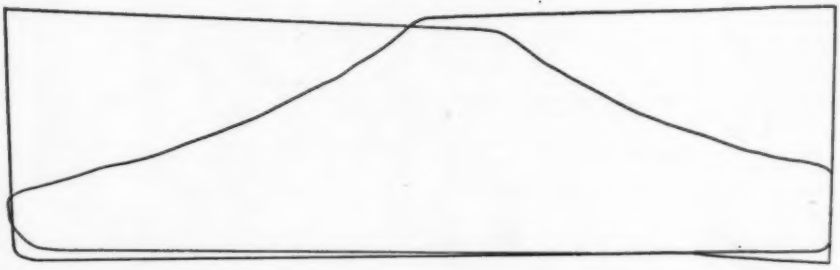


FIG. 8 INDICATOR CARDS OF WORTHINGTON DUPLEX COMPOUND PUMPS
TIME 2:45 P. M., SEPTEMBER 7, 1905



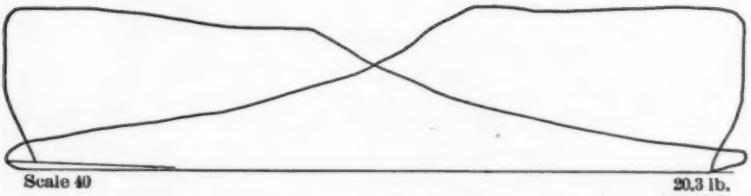
Scale 40

20.2 lb.
29.5 H.P.



Scale 80

79 lb.
73.07 H.P.



Scale 40

20.3 lb.
29.7 H.P.

FIG. 9. INDICATOR CARDS OF LAIDLAW, DUNN, GORDON FLYWHEEL PUMPS
TIME 3:30 P. M., SEPTEMBER 8, 1905

BOILER TEST TO DETERMINE COAL USED BY THE ELEVATOR SYSTEM AND THE APPROXIMATE WATER EVAPORATED. DUPLEX COMPOUND PUMP

Test on No. 3 Babcock & Wilcox 350 horse power Boiler

1	Date of test	September 7, 1905
2	Duration	9 hours, from 8.30 a. m. to 5 30 p. m.
3	A heating surface and grate	3808 and 75.8 sq ft.
4	Fuel	Buckwheat No. 1; $3.40 long ton (11,650 B. t. u.)
5	Steam pressure above atmosphere	maximum, 150; minimum, 140 average, 141 lbs. per sq. in.
6	Draught	Chimney, 1.25; at fire door 0.6 in.
7	Feed water temperature	maximum, 208; minimum, 208 (208 at heater) deg.F.
8	Depth of fire	4 ins.
9	Coal burned	7000 lbs.
10	Coal burned per hour	average, 777 lbs.
11	Ashes	1300 pounds, or 19 per cent of dry coal
12	Moisture in coal	2½ per cent
13	Dry coal burned	6825 lbs.
14	Water evaporated as registered by meter	5490 gal.
15	Boiler horse power developed (approximate)	148.9
16	Per cent rating (approximate)	42½ per cent average
17	Dry coal per hour, average	758 lbs.
18	Number of people going up in elevators	4495

BOILER TEST TO DETERMINE THE COAL USED BY ALL PARTS OF THE PLANT, WITH THE EXCEPTION OF THE ELEVATOR SYSTEM, AND THE APPROXIMATE WATER EVAPORATED

Test on No. 1 Babcock & Wilcox 265 horse power Boiler

1	Date of test	September 7, 1905
2	Duration	9 hours, from 8.30 a. m. to 5.30 p. m.
3	Heating surface and grate	2932 and 59½ sq. ft.
4	Fuel	Buckwheat No. 1; $3.40 long ton (11,650 B. t. u.)
5	Steam pressure above atmosphere	maximum, 150; minimum 140 average, 142 lbs. per sq. in.
6	Draught	Chimney, 1.25 ins. at fire door 0.6 in. lbs. per sq. in.
7	Feed water temperature	maximum, 208; minimum, 208 (208 at heater) deg.F
8	Depth of Fire	4 ins.
9	Coal burned	6100 lbs.
10	Coal burned per hour	average, 677 lbs
11	Ashes	910 lbs, or 15 per cent of dry coal
12	Moisture in coal	2½ per cent
13	Dry coal burned	5948 lbs.
14	Water evaporated as registered by meter	6344 gal.
15	Boiler horse power developed (approximate)	172.2
16	Per cent of rating (approximate.)	65 per cent average
17	Dry coal per hour, average	661 lbs.
18	Ampères	maximum, 700; minimum, 350; average 509
19	Kilowatt hours generated during test	550, at 1.68 cents for coal (50 Kw. General Electric Marine Type)

BOILER TEST TO DETERMINE THE COAL USED BY THE ELEVATOR SYSTEM AND THE APPROXIMATE EVAPORATION. FLY WHEEL PUMP IN USE

Test on No. 3, Babcock & Wilcox 350 horse power Boiler

1	Date of test	September 8, 1905
2	Duration	9 hours, from 8 a. m. to 5 p. m.
3	Heating surface and grate	3,808 and 75.8 sq. ft.
4	Fuel	Buckwheat No. 1 (11,650 B. t. u.)
5	Steam pressure above atmosphere	maximum, 145; minimum, 140 average 144 lbs. per sq. in.
6	Draught	Chimney, 1.25 in.; at fire door 0.6 in.
7	Feed Water temperature	maximum, 206; minimum, 185; average 195 (208 heater) deg. F.
8	Depth of fire	4 ins.
9	Coal burned	4400 lbs.
10	Coal burned per hour	average 489 lbs.
11	Ashes	750 lbs, or 17 per cent of dry coal
12	Moisture in coal	2½ per cent
13	Dry coal burned	4290 lbs.
14	Water evaporated as registered by meter	3800 gal.
15	Boiler horse-power developed (approximate)	104.05
16	Per cent of rating (approximate)	30 per cent average
17	Dry coal per hour, average	476 lbs.
18	Number of people going up in elevators	5040

BOILER TEST TO DETERMINE THE COAL USED BY ALL PARTS OF THE PLANT WITH THE EXCEPTION OF THE ELEVATOR SYSTEM AND THE APPROXIMATE WATER EVAPORATED

Evaporative Test on No. 1, Babcock & Wilcox 265 horse power Boiler

1	Date of test	September 8, 1905
2	Duration	9 hours, from 8 a. m. to 5 p. m.
3	Heating surface and grate	2932 and 59½ sq. ft. (265 horse power rated)
4	Fuel	No. 1 Buckwheat (11,650 B. t. u.)
5	Steam pressure above atmosphere	maximum, 145; minimum, 140 average, 144 lbs. per sq. in.
6	Draught	Chimney, 1.25; at fire door 0.6 in.
7	Feed water temperature	maximum 206, minimum, 198 average, 201 (208 Heater) deg. F.
8	Depth of fire	4 ins.
9	Coal burned	5800 lbs.
10	Coal burned per hour	Average 644 lbs.
11	Ashes	875 lbs. or 15 per cent of dry coal
12	Moisture in coal	2½ per cent
13	Coal burned dry	5655 lbs.
14	Water evaporated as registered by meter	6370 gal.
15	Boiler horse power developed	177
16	Per cent of rating (approximate)	67 per cent average
17	Dry coal per hour, average	628 lbs.
18	Ampères	maximum, 600; minimum, 300; average, 413
19	Kilowatt hours generated during test	446 at 1.96 cents for coal

TESTS OF TRINITY BUILDING ELEVATORS

No. 3 Express load of 1617 pounds in car, Basement to 21st floor. Up in 43 seconds. Average speed 393 feet per minute, highest 438. Down in 27 seconds. Speed, 629 feet per minute.

Overrunning Test

Load of 1617 pounds in car up, 12 feet 4 inches; lost 8 seconds. Speed 490 feet at 11th floor overrun.

Down, 14 feet; lost 9 seconds. Speed 540 at 11th floor overrun.

Basement to 21st floor:

Load of 1617 pounds in car. 6 stops. Up, 1 minute, 25 seconds; repeated, 1 minute, 17 seconds.

Down *1 minute, 8 seconds; repeated, 1 minute, 25 seconds.*

Trips in 2 minutes, 33 seconds; 2 minutes, 42 seconds, respectively.

First floor to 21st floor: stops at 11, 13, 15, 17, 19, 21st floors. *Up, 1 minute, 9 seconds.* Stops at 20, 18, 17, 15, 12, 11th floors. *Down, 1 minute, 1 second.*

Round trip in 2 minutes, 10 seconds. Water pressure, 170 lbs. per sq. in.

CONDITIONS

Stops must be no more than 3 inches out of level.
Open and shut door at each stop.
Stops ordered after door was shut.

Load of 1617 pounds in car up, 1st to 21st floor, stops at 12, 13, 16, 18, 20, 21st floors; *1 minute, 10 seconds.*
Down 21st to 1st floor, stops at 19, 17, 15, 13, 12, 11, 1st, *1 minute, 6 seconds.*
Round trip in 2 minutes, 16 seconds. Water pressure 165 to 185 lbs. per sq. in.

Up 1st to 21st, stops at 11, 13, 15, 17, 19, 21st, *1 minute, 10 seconds.*
Down 21st to 1st, stops at 20, 18, 16, 14, 13, 11, 1st, *1 minute, 4 seconds.*
Round trip in 2 minutes, 14 seconds. Water pressure 165 to 185 lbs. per sq. inch.
Generally excellent stops.

TESTS OF TRINITY BUILDING ELEVATORS

No. 3 express, load of 1617 pounds in car.
Speed, flying test, up 3d to 11th floor; speed 490 ft. per minute.
Water pressure, 180 lbs. per sq in.
Overruning test, up load of 1617 lbs.
Flying test, 3d to 11th floor; speed, 490 feet per minute.
Overrun, 12 feet 4 in; lost time, 8½ seconds.
Overruning test, down. Load of 1617 lbs. in car.
Flying test, 11th to 3d floor, speed, 540 feet per minute.
Overrun, 14 feet; lost time, 9 seconds.

As seen above, an express elevator of the Trinity Building made the round trip—1st to 21st floor—with 1617 lbs. of load, stopping 6 times each way, in 2 minutes and 14 seconds. Doors were opened and shut, good stops insisted on, and no advance orders given.

Express No. 3, load of 1756 pounds in car. Water pressure 185 lbs. per sq. in.

Basement to 3d floor, 10 seconds, speed 279 feet; 3d to 11th, 15 seconds, speed 420 feet.

Up, at a speed of 420 feet, overran 11 feet 6 inches, lost 7 seconds, repeated, overran 10 ft. 6 inches, lost 9 seconds.

Down, 21st to 18th floor, 7 seconds, speed 325 feet; 18th to 11th floor, 6 seconds, speed 885 ft; 11th to 3d floor 14 seconds, speed 450 feet.

Same car load of 1915 pounds in car. Water pressure, 190 lbs. per sq. in.

Up, basement to 21st floor. Highest speed 11th to 18th floor, 531 feet, average 41 seconds, 412 feet.

Down, 21st floor to basement. Highest speed, 18th to 11th floor, 885 feet, average 28 seconds, 600 feet.

Best result overrunning going up 9 feet on 11th floor at 468 foot speed; least time lost, 7 seconds.

Local No. 5, load 653½ lbs. in car. Water pressure 185 lbs. per sq. in.

Up, highest speed 3d to 11th floor, 636 feet, average, 35 seconds 480 feet; repeated with same result.

Down, 21st floor to basement. Highest speed 18th to 11th floor, 590 feet, average 35 seconds, 480 feet.

Local No. 8, four men, load of 653½ pounds in car. Water pressure 185 lbs. per sq. in.

Up, basement to 11th floor. Highest speed 3d to 8th floor, 456 feet, best average, 24 seconds 388 feet.

Down, 11th floor to basement. Highest speed 8th to 3d floor, 411 feet, average 28 seconds or 330 feet; repeated with same result.

Local No. 9 same load. Water pressure 185 lbs. per sq. in.

Up, basement to 11th floor. Highest speed, 3d to 8th floor, 587 feet, best average, automatic, 17 seconds, speed 548 feet.

Down. 11th floor to basement. Highest speed, 8th to 3d floor, 373 feet, best average, 29 seconds, 322 feet.

Local No. 10 same load. Water pressure 185 lbs. per sq. in.

Up, basement to 11th floor. Highest speed; 3d to 8th floor, speed 456 feet, average, 22 seconds or 420 feet.

Down, 11th floor to basement. Highest speed 3d floor to basement 370 feet, average, 30 seconds or 310 feet.

Heights of Floors, Trinity Building

Sub-basement	12 feet 6 inches
Basement	13 feet 6 inches
1st	19 feet 6 inches
2d	16 feet 6 inches
3d to 5th, inclusive	14 feet 6 inches
6th to 16th, inclusive	14 feet 6 inches
17th	13 feet 6 inches
18th	13 feet
19th and 20th	12 feet 6 inches
21st	11 feet

Elevator Travels

Basement to 3d	49½
Basement to 21st	282
Sub-basement to 21st	294½
3d to 8th	68½
3d to 11th	106
2d to 11th	122½
2d to 18th	211
8th to 11th	37½
11th to 18th	88½
18th to 21st	38

ECONOMY TEST OF ELEVATOR SYSTEM WITH DUPLEX COMPOUND PUMP IN USE

September 7, 1905

Record of Data

1 Horse power developed by boiler (approximate).....148.9 average
2 Coal burned in the 9 hours .....7,000 lbs.
3 Quality and cost of coal.....Buckwheat, No. 1; $3.40 long ton
4 Calorific test of coal.....(75.04 fixed carbon; 11,650 B. t. u.)
5 Moisture in coal .....2½ per cent
6 Ashes in pounds 1300
7 Ashes, perc ent of dry coal.....19
8 Evaporation per lb. of coal (approximate.) 6.29
9 Coal, pounds per car mile 53
10 Coal, pounds per kw. h., including house service and all boiler feed.....11
11 Coal, cost per car mile.....8.04 cents
12 Coal, cost per lamp including house service 0.084
13 Coal, cost per kw. h. including house service.....1.68
14 Round trips made by locals, 848—1st to 11th floor—142 feet.
8—Basement to 11th floor—155 ft.
Total distance traveled in one direction, 121,660 feet.
15 Round trips made by express, 793—1st to 21st floor—268.5 ft.
47—Basement to 21st floor—282 feet.
Total distance traveled in one direction, 226.174 ft.
16 Number of feet traveled in one direction, or ½ total travel for day of 9 hours.....347,834
17 Total number feet per hour traveled in both directions.....77,296
18 Average number of car miles per hour.....14.63
19 Elevator fuel per hour, 777 lbs., costing.....1.18
20 Cost of electric and house pump fuel per hour.....1.03
21 Indicated pump horse power (mean of cards) 126.19
22 Mechanical efficiency of pump, per cent.....0.927
23 Water horse power delivered by pumps.....117.9
24 Steam used per mile car travel, lbs. (approximate).....350.5
25 Coal used per mile car travel, lbs.....53
26 Car miles for day of 9 hours.....131.74
27 Pump used.....Henry R. Worthington Duplex Compound, 21x34x18x24
28 Revolutions in 9 hours.....6473
29 Revolutions per minute.....12
30 Slip total, per cent.....4.3
31 Water delivered per revolution, actual in gallons.....99
32 Number of passengers in 9 hours (4495). Round number.....4500
33 Cost of coal per passenger lifted .....0.24 cent
34 Water horse power per car mile 8
35 Actual water pumped, gallons 640,827
36 Average water pressure during day in pounds per sq. in.....176

ECONOMY TEST OF ELEVATOR SYSTEM WITH FLY WHEEL PUMP IN USE

SEPTEMBER 8, 1905

Record of Data

1 Horse-power developed by boiler (approximate) ..... 104.05 average
2 Coal burned in the 9 hours ..... 4400 lbs.
3 Quality and cost of coal ..... Buckwheat, No. 1; $3.40 long ton
4 Calorific test of coal ..... 75.04 fixed carbon; (11,650 B. t. u.)
5 Moisture in coal ..... 2½ per cent
6 Ashes in pounds 750
7 Ashes per cent of dry coal 17
8 Evaporation per pound of coal (approximate) 6.93
9 Coal, pounds per car mile 34.4
10 Coal, pounds per kw. h. including house service and all boiler feed 13
11 Coal, cost per car mile ..... 5.22 cent
12 Coal, cost per kw. h. including house service and all boiler feed 1.96
13 Coal, cost per lamp hour including house service 0.088
14 Round trips made by locals, 861—1st to 11th floor—142 feet.
Also 16—Basement to 11th—155.5 feet.
Total distance traveled in one direction, 124,750 feet.
15 Round trips made by express, 680—1st to 21st floor—268.5 feet.
Also 105—Basement to 21st—282 feet.
Total distance traveled in one direction, 212,190 feet.
16 Number of feet traveled in one direction or ½ total travel for day of 9 hours 336,940
17 Total number of feet per hour traveled in both directions 74,874
18 Average number of car miles per hour 14.18
19 Elevator fuel per hour, 489 lbs costing $0.71
20 Electric and house pump fuel per hour, 644 lbs $0.97
21 Mechanical efficiency of pump ..... 89.6 per cent
22 Indicated pump horse power (mean of cards) 130.29
23 Water horse power delivered by pump 116.7
24 Steam used per mile car travel (approximate) 252.8
25 Saving in steam when compared with compound duplex pump .... 28 per cent
26 Coal used per mile, car travel 34.4
27 Saving in coal when compared with the compound duplex pump .. 35 per cent
28 Car miles for day of 9 hours 127.63
29 Pump used ..... Laidlaw, Dunn Gordon Flywheel, 17¾x22x22x12¼x30
30 Revolutions in 9 hours 13,896
31 Revolutions per minute 25.7
32 Slip total, per cent 3.87
33 Cost of coal per passenger lifted ..... 0.13 cent
34 Number of passengers in 9 hours (5040); round number 5000
35 Water horse power per car mile 8.23
36 Actual water pumped, gallons 612,758
37 Average water pressure during day in pounds per sq. in 177
38 Water delivered per revolution, gallons (actual) 44.09

Elevator Dimensions and other Data

Diameter of all plungers, 6½ in.

Thickness of shell of plunger freight and long run elevator ⅜ in.

Thickness of shell of plunger short run elevator, $\frac{5}{16}$ in.

Plunger weights, total of plunger with central rope, long run passenger elevators, 8460 pounds. Total of plunger with central rope, short run passenger elevator, 4000 pounds.

Counterweights: Freight elevator, 8000 lbs.
Long run elevator, 7900 lbs.
Short run elevator 4700 lbs.

Ropes: Counterweight ropes per foot, 7.2 lbs.
Counterweight, total weight, freight, 2150 lbs.
Counterweight, long run passenger, 2050 lbs.
Counterweight, short passenger, 1121 lbs.

Weights of car:

Frame and panels: freight elevator, 3500 lbs.
long run passenger, 2500 lbs.
short run passenger, 2300 lbs.

Cab Weight: each passenger cab, 1125 lbs.
Friction each machine, up, 500 lbs.
Friction each machine down, 300 lbs.

Cubic contents of building, 3,990,000 cu ft.

Height, 298 feet above curb.

Lot area, 10,920 ft.

Total floorspace, 140,000 sq. ft.

IMPROVED TRANSMISSION DYNAMOMETER

By W. F. DURAND, STANFORD UNIVERSITY, CAL.
Member of the Society

1 The importance to the engineer of instruments and apparatus for the measurement of engineering quantities will perhaps serve as an excuse for bringing to the attention of the members of the Society the form of dynamometer which is the subject of the present paper.

2 At different times during the past eight or nine years the author has had occasion to use a transmission dynamometer in connection with certain investigations on the action of screw propellers. For this purpose a special form of rope or round belt dynamometer was designed and constructed which rendered excellent service. Forms of this dynamometer have been described in other engineering publications.[1] This very considerable experience with one type of service exposed the less satisfactory features of this form of dynamometer, and in the endeavor to produce a perfected apparatus based on such experience, the design described herein was developed. (See Figs. 1, 2 and 3.)

3 In general the conditions imposed were as follows:

a To reduce internal friction to a minimum.

b To eliminate belt slip or creep under heavy loads.

c To provide an apparatus of maximum capacity for given weight of material, and, therefore, of the maximum degree of portability.

d To provide for the measurement of turning moment either by spring balance, by beam scale weighing, or by hydraulic step and pressure gage.

4 A and B are two sprocket wheels mounted on a frame xy which is carried at E by a steel spring support, after the manner of the well-known Emery steel plate knife edge. This is frictionless, and for small movements of the frame the bending stress developed is infinitely small in comparison with the other forces in play. As shown at

[1]Transactions Society Naval Architects and Marine Engineers.

To be presented at the New York Meeting (December, 1906) of The American Society of Mechanical Engineers, and to form part of Volume 28 of the Transactions.

S S, semicircular plates of steel fitted with a slot are carried by the frame, either side of which is held fast to the standard by a pin while the frame oscillates through its permitted range of motion of about one-fourth inch at a distance of ten inches from the center of support. This permits perfect freedom of motion within this range, but prevents movement beyond to such an extent as to develop any sensible force within the steel spring supports.

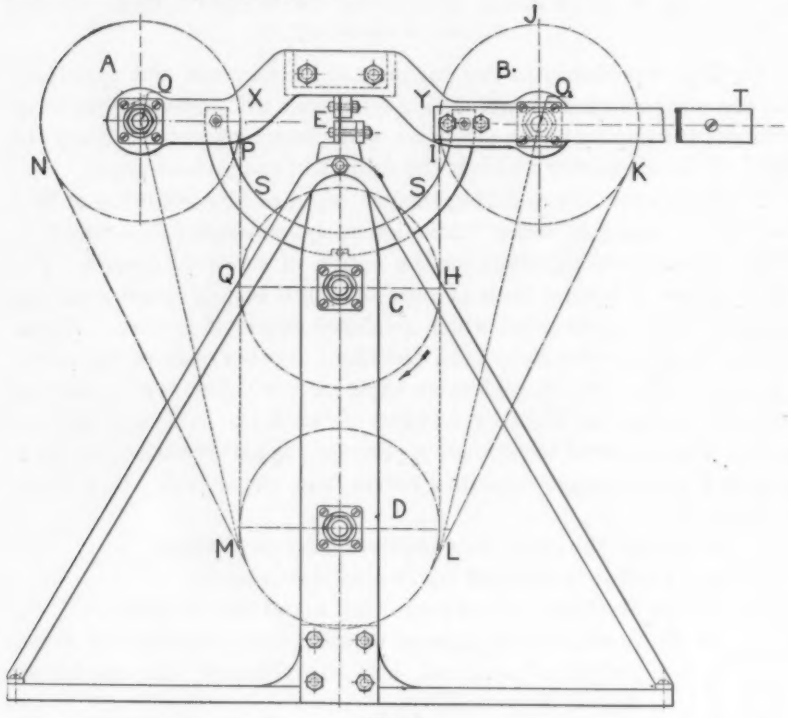


FIG. 1

5 The sprockets *C* and *D* are similar in form and size to *A* and *B* and are mounted on standards attached to the base. All sprockets are mounted on ball bearings in order to reduce friction to the minimum. Around these wheels is led a chain, the dimensions being so adjusted that with the proper length of spring for bearing at *E*, the chain throughout its length will run with the proper amount of slack for smooth and steady operation.

6 The similarity between this form of dynamometer and the Tatham form will be readily noted. The present type may, in effect, be considered as a development of the six-equal-wheel form by the elimination of the two lower wheels and the substitution of chain for belt drive.

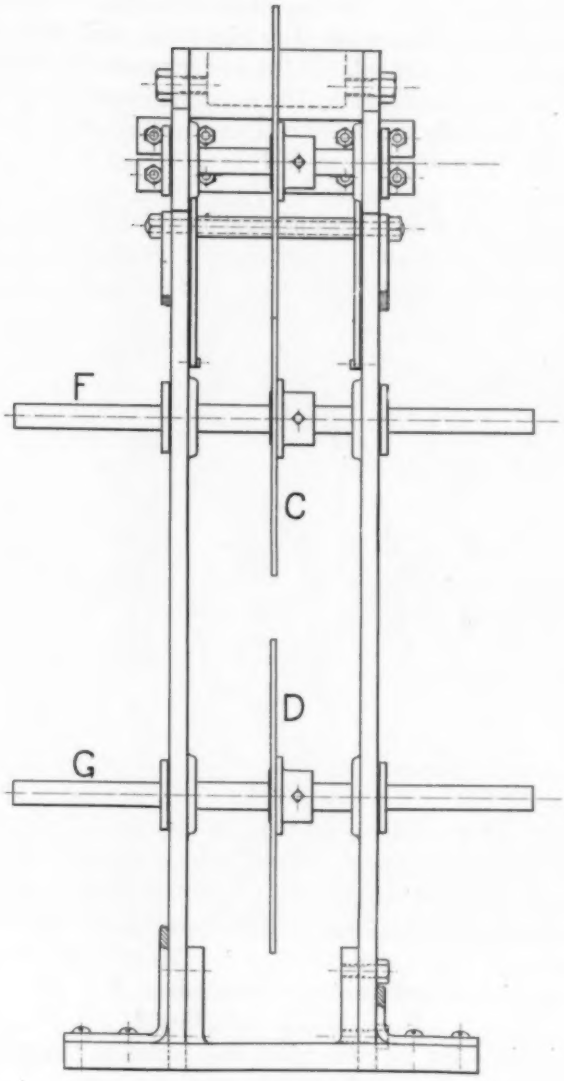


FIG. 2

7 The shafts which carry the sprockets C and D are extended, carrying pulley wheels at F and G, Fig. 2, and also universal joint couplings for direct connection to a driver or follower. The power can be put in at C and taken out at D or vice versa, and on either side of the dynamometer as desired. If the power passes through from C to D, and C turns as indicated by the arrow, it is readily seen that the tight side of the chain will be from H around through $I\ J\ K\ L\ M$, and the loose side from M, through $N\ P$ to Q. Thus $H\ I$ and $K\ L$ will, under the higher or driving tension T_1, be equal on both sides except for the small friction of the ball bearing on which B turns. Likewise, $M\ N$ and $P\ Q$ will, under the same loose or following tension T_2, be the same on both sides except for the friction of the ball bearing on which A runs.

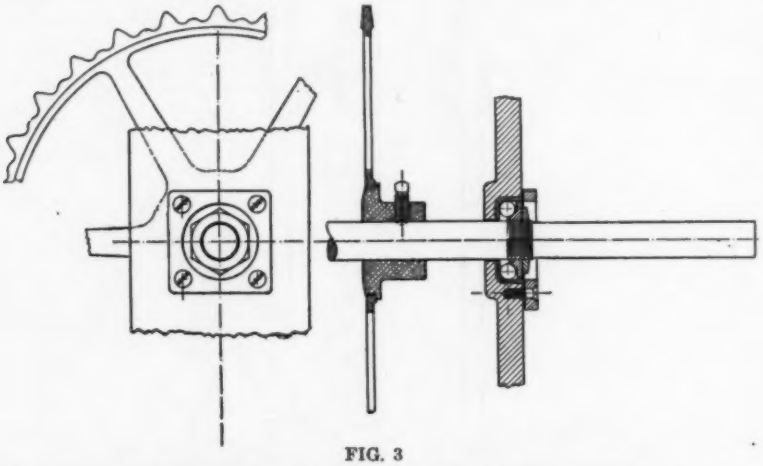


FIG. 3

8 Disregarding these small frictional resistances, the two tensions T_1 will have the resultant $2T_1 \operatorname{Cos} \theta$ directed along the line $O_1 L$, while the two tensions T_2 will have the resultant $2T_2 \operatorname{Cos} \theta$ directed along $O M$. The components of these forces perpendicular to the line $O O_1$ will be in each case $2T_1 \operatorname{Cos}^2 \theta$ and $2T_2 \operatorname{Cos}^2 \theta$. Denoting the distance $O_1 E$ by a we have for the net turning moment about E

$$M_1 = 2a\ (T_1 - T_2) \operatorname{Cos}^2 \theta$$

9 Again denoting by r the pitch line radius of the sprockets, we have for the power taken off at D the turning moment

$$M_2 = r\ (T_1 - T_2)$$

$$\text{Hence } M_2 = \frac{M_1\ r}{2a \operatorname{Cos}^2 \theta}$$

$$\text{and work per } mt. = 2\ \pi\ N\ M_2 = \frac{\pi\ N\ M\ r}{a \operatorname{Cos}^2 \theta}$$

10 Obviously the two tensions T_1 on the right, acting against the two tensions T_2 on the left will determine a moment tending to depress the end T of a lever attached to the frame xy. If we denote $E\,T$ by h and the force at T required to balance the moment by F we shall have

$$M_1 = Fh \text{ or}$$

$$\text{Work per } mt. = \frac{\pi N F r h}{a \operatorname{Cos}^2 \theta}$$

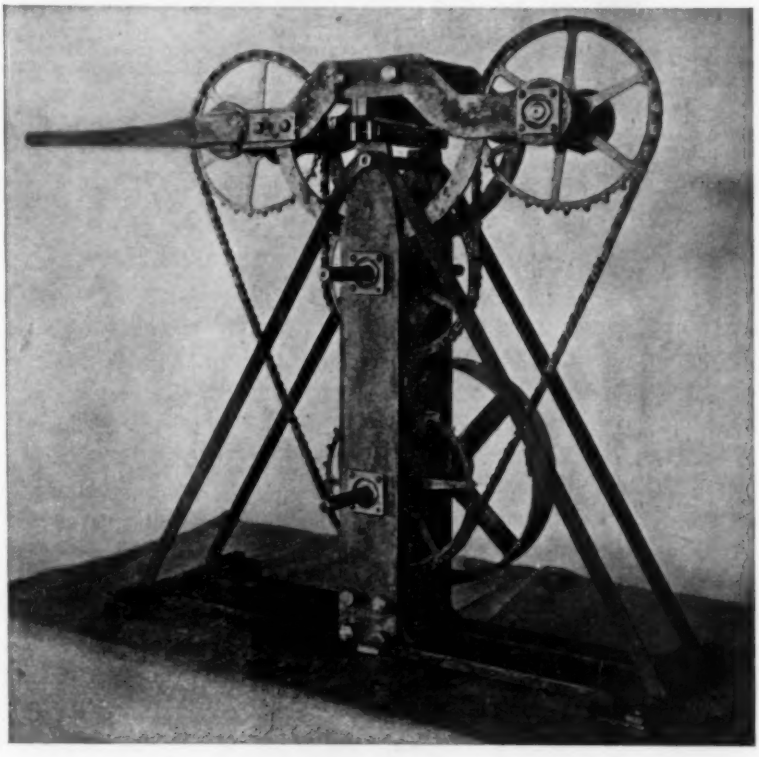


FIG. 4

11 By careful measurement of the dimensions of the dynamometer the relation between the power transmitted and the observed values of N and R can be determined. As in all cases involving the use of such apparatus, however, it will be more satisfactory to calibrate directly by mounting a friction brake on a belt wheel attached to the delivery shaft and noting the relation between brake readings and the values of the force R. Such a calibration will of course serve to eliminate all

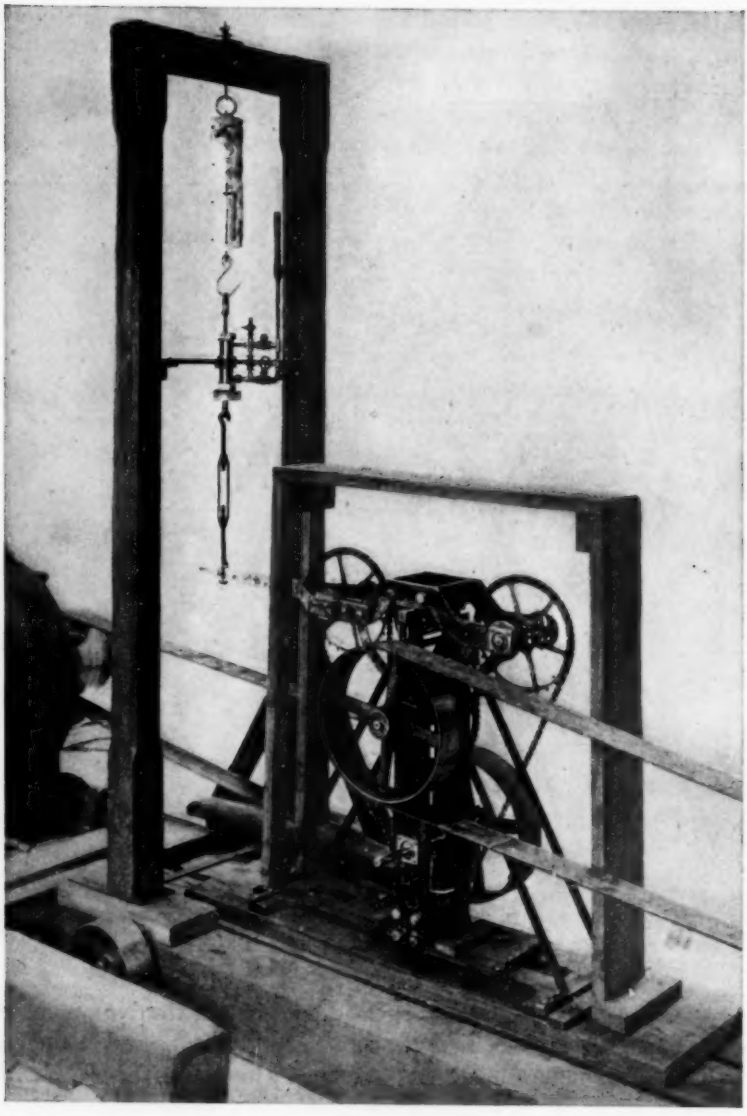


FIG. 5

friction between the points of intake and delivery, or in the dynamometer itself, and will thus serve to correctly relate the force records as measured by R with the actual power delivered.

12 In the case of the dynamometer under present notice the relation in question was determined by both methods—measurement and computation, and by experimental calibration. The difference should then be an indication of the amount of power absorbed by the friction of the apparatus. The tests indicated but slight friction in the chain and bearings, which might have been expected from the character of the design and construction.

13 The chief dimensions of the dynamometer shown in the figures are as follows:

Diameter of sprocket wheels	9 in.
Diameter of shafts	$\frac{3}{4}$ in.
Size of chain	$\frac{3}{10}$ in. wide
Height over all	30 ins.
Width of base	12 ins.
Length of base	30 ins.

14 The capacity of the dynamometer as constructed was intended to run to some 5 or 6 horse power. Certain experiments requiring somewhat more power presented themselves, however, and the dynamometer was successfully used up to about 12 horse power, but this is more than was intended and is beyond the proper limit for sprockets, chain, and bearings of these dimensions.

15 In terms of revolutions no trouble was experienced in running the dynamometer up to 800 or 900 r.p.m., speeds which would with difficulty be realized with a rope or belt driven dynamometer.

16 A larger dynamometer of the same type is under present construction in which 12 inch automobile sprockets and 5000 pound chain sprockets will be used, and with which a capacity of about 50 horse power should be realized.

STEAM TURBINE CHARACTERISTICS

By HANS HOLZWARTH, OF HAMILTON, OHIO
Non-Member

1 With reciprocating engines it has become familiar practice to consider the indicator diagrams of the engine as characteristics of its thermodynamical qualities.

2 These characteristics are used by the designer of the engine as fundamental bases for the design of the skeleton of the engine and by the engineer for controlling the engine while running.

3 Are there similar characteristics for steam turbines, that can be advantageously used by the turbine designer as well as by the engineer in charge of a power plant equipped with steam turbines?

4 While we have consecutive cycle processes in the reciprocating engines, we have a continuous open process in steam turbines as in water turbines.

5 This is the continuous open process in steam turbines: steam admitted to the turbine with a certain amount of total heat at a certain initial pressure, taken away from the turbine with a smaller amount of total heat at a smaller exhaust pressure. The steam continuously expanding within the turbine and thus converting the difference between initial total heat and exhausting total heat into mechanical energy is a perfect, ideal process without any losses when the output of energy at the turbine shaft is equal to the difference in the amounts of the initial and exhausting total heats.

6 The characteristics of the turbine as to its thermo-dynamical qualities, therefore, must show the amount of available energy or available total heat and the amount of accomplished mechanical energy.

7 The ratio of these two factors is the total efficiency of the turbine.

8 For multiple expansion turbines (all but de Laval turbines) this open process is composed of a multitude of part-processes in the individual stages of the turbine.

9 The characteristics of the turbine have to show of course graphical interpretations of these part processes.

[1]To be presented at the New York Meeting (December, 1906) of The American Society of Mechanical Engineers, and to form part of Volume 28 of the Transactions.

10 The general law for steam expansion is:

$$p \times v^n = \text{Const.}$$

p = absolute pressure of steam;
v = specific volume of steam;
n = expansion coefficient.

11 The total energy that is available from an open expansion process between the initial pressure p and the exhausting pressure p_0 is:

$$L = \int_{p}^{p_o} v \, dp$$

or in heat equivalents,

$$I = A \times L$$

where A = heat equivalent of mechanical energy

$$= \frac{1}{427} \text{ in metric system}$$

$$= \frac{1}{778} \text{ in British system}$$

and for adiabatic expansion,

$$I = i - i_0$$

where I = available total heat,
i = initial total heat,
i_0 = exhausting total heat.

12 Mere algebraical computations with this general expansion law $p \times v^n = \text{Const.}$ are rather complicated, and, therefore, self-forbidding for the engineer.

13 The graphical interpretation is the only practical way to work with this law.

14 The common $p = v$ diagram with absolute steam pressures as ordinates and specific steam volumes as abscissas is generally known.

15 The shaded area is the graphical interpretation of the available expansion energy.

$$L = \int_{p_o}^{p} p \, dv$$

16 When this diagram is laid out in a certain scale, the amounts of available energy are directly represented by the areas between the

respective pressure lines; the amounts of available energy, therefore, can be directly measured with the planimeter and the whole expansion area can be divided into parts of equal expansion area, corresponding to equal part expansions.

17 This common $p - v$ diagram immediately shows the specific steam volumes after each part expansion to be used for computing the necessary area of the vane or nozzle openings.

18 But it is evident that this diagram has many grave disadvantages for the turbine designer and engineer.

19 The $p \times v^n = \text{Const.}$ curve has to be laid out for each different initial p and v. For superheated steam the curve will be rather complicated, as it consists of two different branches of curves, joining at the point where the superheated steam changes into saturated steam.

20 The part areas in the low pressure zone are very inaccurate, the $p\,v^n = \text{Const.}$ curve being there nearly parallel to the v axis.

21 Furthermore the whole diagram is not flexible and transparent enough to allow quick changes in the layout of the different part expansions.

22 Finally it does not show at a glance what happens when the initial pressure is lower than the boiler pressure; what happens when the initial pressure is raised or lowered; what happens when the exhaust pressure is raised or lowered; what happens when both these pressures are changed simultaneously, and it does not show at a glance the available total heat of the steam, and the influence of moist or superheated steam. In short, it is not a diagram that can be used as a turbine characteristic for practical purposes.

23 A diagram that answers in a better way these requirements is the following logarithmical $p-v$ diagram.

24 Although the method of using logarithmical ordinates has been known for some time, the following use of a logarithmical diagram has never been referred to in literature, as far as my knowledge reaches.

25 In this logarithmical diagram the logarithms (Brigg's) of the different values of steam pressure p are used as ordinates and the logarithms of the specific volumes v are used as abscissas, both obtained from the logarithmical scales on the slide rule.

26 The expansion line

$$p \times v^n = \text{Const.}$$

changes logarithmically into

$$log\ p + n \times log\ v = \text{Const.}$$

that is, graphically, a straight unbroken line for a certain value of n.

27 For $n = 1$ (Mariotte) this line can easily be laid out as

$$\left(\frac{p}{p_o} = \frac{v^o}{v}\right)$$

for $n = 1.135$ (adiabatic expansion) we find the line

$$p \times v^{1.135} = \text{Const.}$$

by multiplying *tan.* α with 1.135 $\therefore$

$$tan.\ \beta = 1.135\ tan.\ \alpha$$

The line $p \times v^n = \text{Const.}$ always starting at the point (p, v) initial.

28 For superheated steam the $p \times v^n = \text{Const.}$ line is logarithmically a broken line composed of two straight lines, joining at the point where the superheated steam changes into saturated steam.

$n = 1.135$ for dry saturated steam;
$n = 1.3$ for superheated steam (approximately).

29 The amount of available energy for a certain open expansion process is:

for $p \times v = \text{Const.}$ (Mariotte) in metric system

$L = 10{,}000 \times p \times v \times (log\ nat\ p - log\ nat\ p_o)$ p and p_o in *kg.-cm.*^{2} *abs.* L in *mkg.* for 1 *kg.* steam per second, or:

$$L = 23{,}100 \times p \times v\ (log\ p - log\ p_o)$$

for instance,

$p = 10$ *kg.-cm.*^{2} *abs.*
$p_o = 0.1$ — — —
$L = 23{,}100 \times 10 \times 0.196\ [1 - (0. - 1)]$
$= 90\ 500$ *mkg.*

and for

$$p \times v^{1.135} = \text{Const.}$$

(dry saturated steam expanding adiabatically) we have empirically in metric system

$$L = 270{,}000 \times \frac{log\ p - log\ p_o}{6.82 - 0.9\ log\ p_o}$$

L in *mkg.*
p and p_o in *kg.-cm.*^{2} *abs.*

and for

$p_o =$	.1 *kg.-cm.² abs*	$6.82 - 0.9 \log p_o$	$= 7.72$
	.5 — — —		$= 7.09$
	1.0 — — —		$= 6.82$
	2.0 — — —		$= 6.55$
	3.0 — — —		$= 6.40$
	4.0 — — —		$= 6.28$
	5.0 — — —		$= 6.20$
	6.0 — — —		$= 6.12$
	7.0 — — —		$= 6.06$
	8.0 — — —		$= 6.01$
	9.0 — — —		$= 5.97$
	10.0 — — —		$= 5.92$

30 For average practical conditions, exhaust pressure ranges from 0.1 to 1 *kg.-cm.² abs.*

We can abbreviate the above empirical formulae into:

$$L = \frac{270{,}000}{7.7} \times (\log p - \log p_o)$$

$$\text{to } \frac{270{,}000}{6.8} \times (\log p - \log p_o)$$

$$= 35{,}000 \times (\log p - \log p_o)$$

$$\text{to } 40{,}000 \times (\log p - \log p_o)$$

for instance,

$p = 10$ *kg.-cm.² abs.*, $p_o = 0.1$ *kg.-cm.² abs.*

$L = 35{,}000\ [1 - (0.0 - 1)]$

$L = 70{,}000$ *mkg.*

against 90,500 with the Mariotte line.

Within the above-mentioned limits the amount of available expansion energy L is directly proportional to

$$\log p - \log p_o$$

that is to the geometrical height in terms of our diagram, of our expansion trapezium.

31 In other words in Fig. 2 the vertical geometrical distance between p and p_o is directly a scale for the amount of available energy for expansion processes within these limits.

32 For instance,

$p = 10$ *kg.-cm.² abs.*; $p_o = 0.1$ *kg.-cm.² abs.*

$h = 125$ *mm.* $= 70{,}000$ *mkg.*

1 *mm.* $= 560$ *mkg.*

33 This important simple and practical rule can be applied to the

$$p \times v^{1.135} = \text{Const.}$$

line with the above-mentioned restrictions, or to the $p \times v = \text{Const.}$ line without any restrictions at all.

34 Considering two consecutive part expansions between the pressure limits,

$$p_1,\ p_2,\ p_3$$

we find the available amounts of energy,

$$L_{1\text{-}2} = 270{,}000\ \frac{log\ p_1 - log\ p_2}{6.82 - 0.9\ log\ p_2}$$

$$L_{2\text{-}3} = 270{,}000\ \frac{log\ p_2 - log\ p_3}{6.82 - 0.9\ log\ p_3}$$

and their ratio:

$$\frac{L_{1\text{-}2}}{L_{2\text{-}3}} = \frac{log\ p_1 - log\ p_2}{log\ p_2 - log\ p_3} \times \frac{6.82 - 0.9\ log\ p_3}{6.82 - 0.9\ log\ p_2}$$

35 For practical cases, where the part expansions only cover a pressure limit ranging from 3 to 4 *kg.* as maximum, the factor

$$\frac{6.82 - 0.9\ log\ p_3}{6.82 - 0.9\ log\ p_2}$$

is for instance,

$$p_1 = 10;\ p_2 = 7 \quad \frac{6.82 - 0.9\ log\ p_3}{6.82 - 0.9\ log\ p_2} = 1.02$$

$$p_1 = 7;\ p_2 = 4 \quad = 1.03$$

$$p_1 = 4;\ p_2 = 2 \quad = 1.04$$

which means for practical figuring we can say that the ratios of the part expansions are directly proportional to the geometrical height of the trapeziums in the logarithmical $p - v$ diagram, or in other words: Within limits, accurate enough for practical purposes, the areas of equal expansion energy are represented in the logarithmical diagram by trapeziums of equal geometrical height.

36 As soon as the value L of the total expansion is known (see paragraph 29), the amount L of each part expansion can be directly measured with any ordinary scale. A slide rule, therefore, is the only tool required for operating with this logarithmical $p - v$ diagram.

37 At a glance we can obtain from this diagram readings listed as follows:

38 (A) By raising the exhaust pressure and correspondingly raising the initial pressure, the total output the of turbine will be in-

creased. Speaking in terms of the logarithmical diagram: by sliding the whole trapezium $p\,v - p_o\,v_o$ along the $p\,v = \text{Const.}$ line upwards, the available energy in 1 *kg* of steam remains the same, the available velocities in the individual stages remain the same, the specific volumes of the steam decrease, and consequently through the same vane area with the same velocities an increased weight of steam is flowing through the turbine, and, therefore, more energy is available at the switchboard.

39 (B) By lowering this trapezium along the $p\,v^n = \text{Const.}$ line, which means decreasing exhaust and initial pressures correspondingly so that the available steam energy remains constant, the total output at the switchboard will be decreased. The volumes in the individual stages being increased, and the steam velocities and vane areas remaining constant, a reduced weight of steam only can pass through the turbine, and, therefore, the output at the switchboard is decreased.

40 In both cases the total efficiency of the turbine is affected by the rotation and steam passage losses, varying with the specific volumes of the steam. The latter operation will result in a better efficiency than the first one.

41 (C) Increasing the trapezium towards the exhaust pressure lines, decreasing exhaust pressure, and keeping initial pressure constant means an increase of the available energy in direct proportion to the geometrical heights of the respective trapeziums, which results in an increase in steam velocities in the individual stages and increased specific volumes of the steam. Whether an increased weight of steam can flow through the turbine cannot be decided without reference to concrete figures. But whether the weight of the steam can be made greater or not, at any rate the output at the switchboard will be increased, the pressure upon the running vanes being heavier with increased velocity. The rotation and steam passage losses will be decreased.

42 (D) Raising the trapezium towards the initial pressure lines—increasing initial pressure and keeping exhaust pressure constant—results again in an increase of the available energy in direct proportion to the geometrical height of the respective trapeziums.

43 The velocities in the individual stages are increased, the specific steam volumes are decreased with the exception of that in the last stage. Therefore, an increased weight of steam can travel through the turbine and the output at the switchboard is correspondingly increased. At the same time the rotation and steam passage losses are greater.

44 (E) Enlarging the trapezium in both directions—increasing

initial pressure, decreasing exhaust pressure—corresponds to an increase in available energy in direct ratio to the geometrical heights of the respective trapeziums. The velocities are increased, the specific volumes partly increased, partly decreased, at any rate the same weight of steam will give a considerably greater output of energy at the switchboard.

45 (F) The question of the overloading capacities of steam turbines can easily be discussed with this diagram: the overload capacity of a steam turbine can be accomplished with or without by-passing steam to the low pressure zone.

Without by-pass steam it can be accomplished by raising the initial pressure and keeping exhaust pressure constant (discussed under D), or by raising exhaust and initial pressures simultaneously (discussed under A).

46 Admitting live steam to the low pressure parts of the turbine does not necessarily involve a considerably larger output at the switchboard. This additional steam can be supplied to the original steam that worked already in the h. p. zone, either with its full static pressure and no initial velocity (at least insignificant against the velocity of the original steam), or with a high initial velocity and a static pressure equal to that of the original steam at the inlet of the by-pass steam.

47 In the first case the by-pass steam exerts a back pressure upon the original steam equal to the static pressure of the by-pass steam. If this pressure is equal to the initial pressure of the original steam, this original steam cannot accomplish any useful energy in the h. p. zone at all, and all the considerably increased rotation and steam passage losses in this h. p. zone have to be entirely compensated by the L. P. zone.

48 In the L. P. zone of course the amount of useful energy is considerably increased. The total available energy of the steam has to be converted into useful energy only in the L. P. zone and therefore increased steam velocities allow an increased weight of steam to pass through the L. P. zone.

49 When supplying by-pass steam to the original steam with a static pressure equal to that of the original steam at the meeting point, but with a considerably increased steam velocity, then the h. p. zone works just as before, initial and exhaust pressures being the same and the L. P. zone has the same available energy and in addition an increased weight of steam can pass through the L. P. zone according to the very great initial velocity of the by-pass steam. Therefore, the overload can be accomplished without sacrificing the h. p. zone.

50 By tapping the individual stages at similar points and registering the static steam pressures, it is very easy by means of this logarithmical diagram to discover any irregularities in the expansion processes of these individual stages.

51 The vane and leakage areas can be easily checked with this diagram. For instance: two similar individual stages, that are supposed to do equal work, have been checked as to their static initial and exhaust pressures; the values of these pressures are plotted in the logarithmical diagram on the $p - v$ line. The geometrical heights of the respective trapeziums show the ratio of the amounts of available energy in the individual stages. If these heights are not alike, the available energies differ in the stages. The reason for this must be that either the vane + leakage area is too small in the stage with the higher trapezium or the vane + leakage area is too big in the stage with the lower trapezium.

52 While this logarithmical diagram answers in an almost perfect way all the requirements for a practical turbine characteristic, as far as the pressure conditions in the turbine are concerned, it cannot directly answer all the thermodynamical questions, for instance: questions as to the influence of moist and superheated steam, or as to the effect of throttling the steam with a regulating valve.

53 These questions can be answered with a very ingenious turbine diagram, first suggested by Professor Mollier, Dresden, Germany, in "Zeitschrift des Vereins Deutscher Ingenieure," 1904, p. 272.

54 To make this paper a complete one the Mollier I–S diagram may be added here.

The ordinates represent the amounts of total heat (above 32° F.) in metric system.

55 The space above the heavy line represents the superheated zone, the heavy line represents the dry saturated zone and the space below the heavy line the moist steam zone.
For instance:

Open expansion process between p = 10 *kg.-cm.*² *abs.*
or p = 10 *at.*
and p_o = 0.1 *at.*
The total heat at the initial point is i = 663 WE for 1 *kg.* steam per second at the exhausting point: i_o = 496 WE
The available total heat, therefore, is $I = i - i_o$ = 167 WE.

[L in *mkg.* = $427 \times 167 = 71\ 300$ *mkg.* while our empirical formula gave $L = 70\ 000$ *mkg.*] (See paragraph 30.)

Throttling this dry saturated steam of 10 *kg.* initial pressure down

to 5 *kg.-cm.*² *abs.* within the regulating valve means, in the terms of this diagram, a horizontal line to pressure line 5 *at.* as no heat energy is lost with this throttling operation. The vertical from this point to the 0.1 at line shows an available energy of

$$144 \text{ WE}$$

that means only

$$\frac{167-144}{167}\times 100 = 13.7\%$$

less than with full 10 *kg.* initial pressure.

56 The starting point of our vertical expansion line is shifted from:
10 *kg.-cm.*² *abs.* dry saturated 180° C. to
5 *kg.-cm.*² *abs.* superheated by 27°; 170° C. the exhaust point is shifted from
0.1 *kg.-cm.*² *abs.* about 22% moisture to
0.1 *kg.-cm.*² *abs.* about 18% moisture (important for the condenser).

57 Transferring this diagram of the throttling operation to our logarithmical diagram (see Fig. 2) we find the starting point on the line 5 *kg.* but outside of the original $p-v$ line, according to the increased volume by 27° superheat.

$$v_{sup} = .377 + 50.9\,\frac{27}{50{,}000} = .405$$

The superheated steam changes into saturated at 4.1 *kg.-cm.*² *abs.* and from here on the $p-v$ line is running parallel with the original

$$p\,v^{1.135} = \text{Const. line.}$$

58 This characteristic shows us that by throttling the steam from 10 *kg.* to 5 *kg.* less steam is passing through the turbine on account of increased steam volume and decreased steam velocities. The available energy is reduced by 13.7%. The rotation and steam passage losses are decreased, therefore the total efficiency of the turbine will not be materially affected by this throttling operation. Concrete figures of course can only be given with concrete turbine designs.

59 This again plainly demonstrates the advantage of the good economy of wide load ranges over reciprocating engines.

60 Another instance showing the wide application of this diagram: Steam of 10 *kg.-cm.*² *abs.* initial pressure and 3% moisture has to be throttled down to about 3 *kg.-cm.*² *abs.* to make the steam dry saturated. And this is without adding any additional heat to it.

61 The logarithmical diagram in conjunction with this heat diagram can be considered as true, simple and, therefore, practical characteristics of the steam turbine.

APPENDIX

62 The following *specific* example may show how the preceding formulae and reasonings of this paper can be applied to distinctly show the influence of:

a Throttling the steam before it enters the turbine (decreasing initial pressure);

b Dropping the vacuum (increasing exhaust pressure);

upon the output and the economy of a steam turbine the speed of the turbine to remain constant.

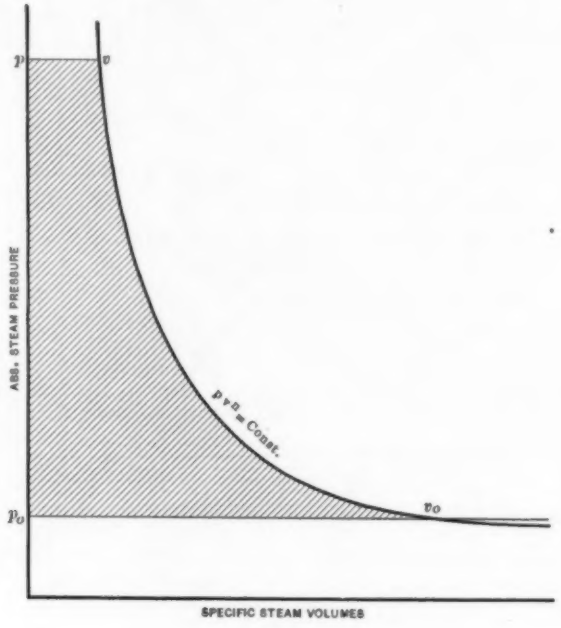


FIG. 1

63 To facilitate this demonstration we will assume a steam turbine with pure pressure action stages only, the vanes to be arranged in these stages, so that their mean diameter is alike all through the turbine.

64 This mean diameter to be .7 *m*. (27½″), the normal angular velocity to be 3600 r.p.m.

65 Therefore, the mean circumferential velocity is $.7 \times \frac{\pi \times 3600}{60}$

$= 131$ *m.-sec.*

66 This turbine to be normally designed for 10*kg.-cm.*^{2}*abs.* (130 lbs. square inch gage) initial pressure, dry saturated steam. .1 *kg.-cm.*^{2} *abs.* (27″ vacuum) exhaust pressure (the same conditions as in the examples of the preceding paper).

67 The available energy is

$$L = 70{,}000\ mkg.$$

(see p. 437).

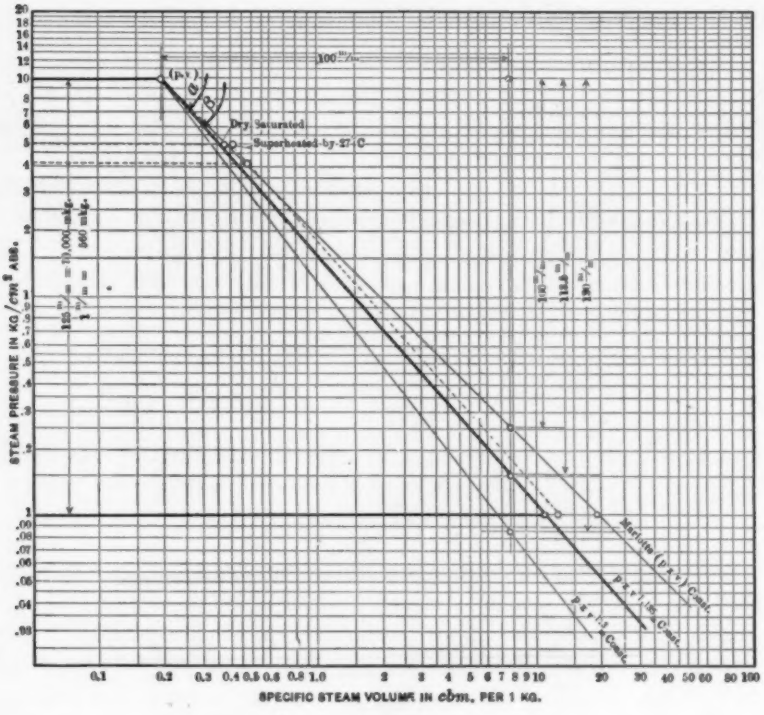

STEAM PRESSURE IN KG./CM.² ABS.
SPECIFIC STEAM VOLUME IN cbm. PER 1 KG.
Dry Saturated
Superheated by 27°C
Adiabatic (p v^1.13) Const.
p v^1.13 = Const.
p v^1.14 = Const.

FIG. 2

The above cut has been reduced from author's original in the ratio of 1 to 2.55. To use it graphically to scale measurement should be multiplied by this coefficient.
To obtain readings in pounds per square inch multiply real ordinates by 14.2202.

68 This energy may be converted into mechanical energy in *ten* pressure stages, each one to convert 7000 *mkg.* into mechanical energy.

69 Assuming that the sum of all the skin friction-whirl-eddy losses within the stationary blades, that is, between the exit edge of one running wheel and the entrance edge of the next following, is 20

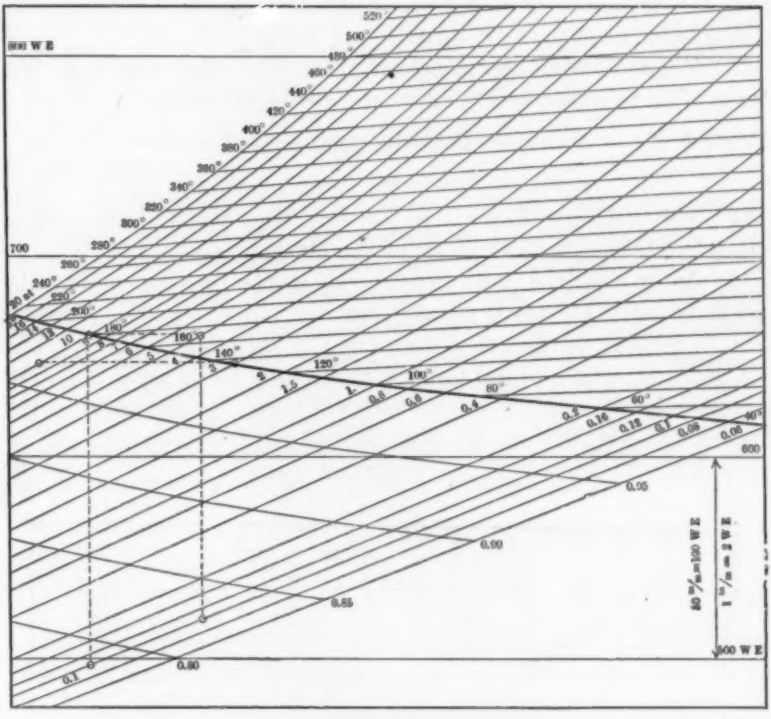


FIG. 3 MOLLIER I–S DIAGRAM

The above cut has been reduced from author's original in the ratio of 1 to 1.87. To use it graphically to scale, measurements must be multiplied by this coefficient.

To obtain readings in pounds per square inch multiply real ordinates by 14.2202.

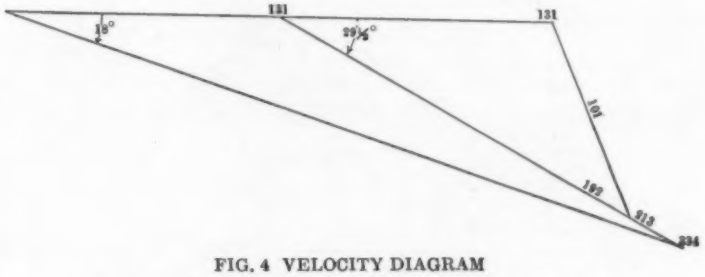


FIG. 4 VELOCITY DIAGRAM

To obtain readings in feet per second multiply real ordinates by 3.28

per cent of this available energy plus the exhausting velocity energy from the preceding running wheel, then only 5600 *mkg.* remain available for each running wheel.

70 The equivalent steam velocity (absolute inlet velocity of the steam with reference to the running vane is, therefore,

$$= \sqrt{2\,g \times 5600}$$
$$= 334\ m.\text{-}sec.$$

71 This velocity diagram is laid out after well-known turbine principles, taking the exit angle of the stationary vanes at 18°.

72 As we took the mean diameter of all the running vanes alike and distributed the work equally over the ten stages, this diagram (Fig. 4) represents the velocity diagram of the whole turbine. The exit and inlet angles of the running vanes have to be made 29½°, the average relative velocity, with which the steam travels between the running vanes is 202.5 *m.-sec.*, assuming 10 per cent velocity losses on account of skin friction on the running vanes.

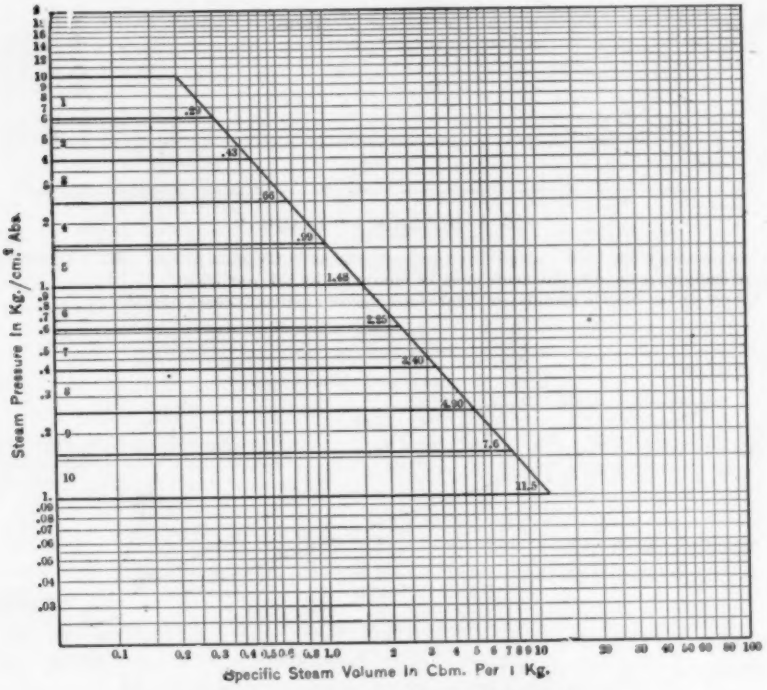


FIG. 5 LOGARITHMICAL p–v DIAGRAM

The above cut has been reduced from author's original in the ratio of 1 to 2.208. To use it graphically to scale, measurements should be multiplied by this coefficient.

To obtain readings in pounds per square inch multiply real ordinates by 14.2202.

73 The absolute exit velocity is 101 *m.-sec.*, the corresponding amount of energy is

$$\frac{101^2}{2g} = 520\ mkg.$$

74 This amount to balance part of the losses in the following stationary blade.

75 By splitting the height of the main expansion trapeziums into ten equal parts, we have seen that these ten part expansion trapeziums represent the expansion zones of the individual stages, stating initial and exhaust steam pressures for each stage, specific steam volumes at the outlet from the stationary blades, and static steam pressure differences which the stationary blades have to stand.

76 The static pressures P, exerted by the steam upon the running vanes when passing between them, is equal to the mass (m) of the steam *pr.* second, multiplied by the relative velocity (w) and the deflection constant. This deflection constant is in our turbine

$$= 1 + cos\ (2\times 29\tfrac{1}{2})^\circ = 1.515$$

or

$$P = 1.515 \times 202.5 \times m.$$

77 The amount of energy, converted into useful energy in each one of these running wheels is

$$L_u = P \times 131$$

(mean circumferential velocity of the running vanes being 131 *m.*).

The equivalent in B. H. P. is:

$$N = \frac{P \times 131}{75} \quad \text{for each wheel.}$$

78 For these equations only the mass of the steam *pr.* second has to be inserted.

79 Taking 1 *kg.* steam per second traveling through the turbine, we have a total pressure upon all the vanes of one running wheel.

$$P = 1.515 \times 202.5 \times \frac{1}{9.87} = 31.1\ kg.$$

80 The useful energy of one wheel is

$$L_u = 31.1 \times 131 = 4090\ mkg.$$

while 5600 *mkg.* have been available; running vane efficiency there-

fore is 73 per cent, and the equivalent in B. H. P. is

$$N = \frac{4090}{75} = 54.3 \text{ B. H. P.}$$

for each running wheel. Subtracting from this amount the rotation loss of the individual running wheel, we get the amount of available B. H. P. at the shaft of each wheel and subtracting from the sum of these values the amount of B.H.P. necessary to overcome the bearing friction we get the total amount of B.H.P. available at the turbine shaft.

81 In other words (neglecting the leakage loss in the stationary blades, the rotation losses and the friction losses in the bearings) this turbine will perform

543 B.H.P.
with 1 *kg.* steam per second;
with 10 *kg.-cm.*^{2} *abs.* initial pressure dry steam;
.1 *kg-cm.*^{2} *abs.* exhaust pressure.

We expect from this turbine (bearing in mind the above-mentioned restrictions) a steam consumption of

$$\frac{3600}{543} = 6.65 \text{ } kg. \text{ B.H.P. hour}$$

82 The openings F_{st} between the stationary vanes have to be:

$$F_{st} = \frac{G \times v}{c}$$

F_{st} = opening between the stat. vanes;
G = weight of steam per second;
v = specific volume of steam;
c = *abs.* exit velocity from stat. blades.

83 In our case,

$$G = 1 \text{ } kg. \text{ and } c = 334 \text{ } m.$$

are constant for all the ten stages; therefore, for F_{st} in square meters

$$F_{st} = \frac{1}{334} \times v$$

=	.00087	.00129	.00197	.00296
	.00445	.00675	.0102	.0146
		.0227	.0345	

for the consecutive stat. blades.

84 The openings between the running vanes have to be at least

$$F_r = \frac{G \times v}{w}$$

in our case

$$= \frac{1}{192} \times v \text{ (square meters)}$$

$$= .00151 \quad .00224 \quad .00342 \quad .00515$$
$$.0077 \quad .0116 \quad .0177 \quad .0255$$
$$.0395 \quad .060$$

for the consecutive running wheels.

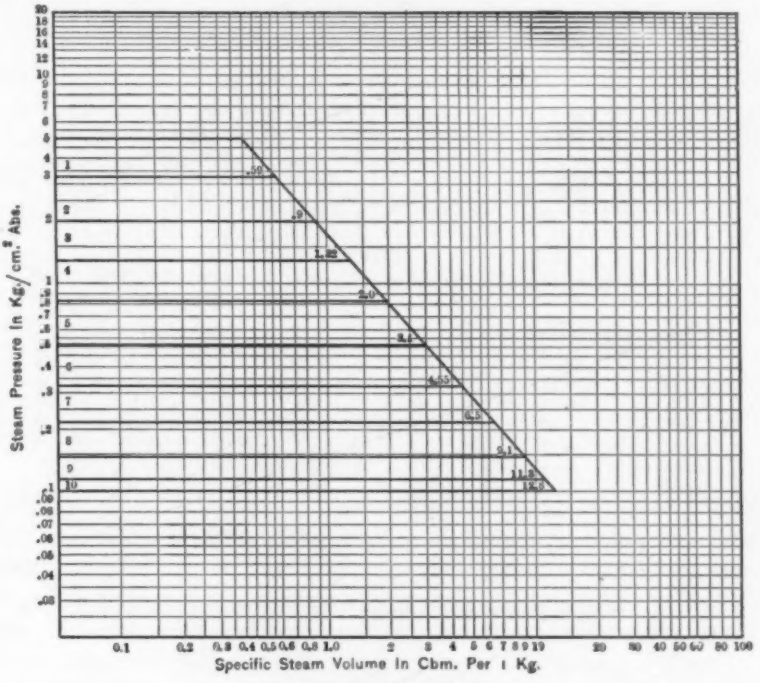


FIG. 6 *P–v* DIAGRAM

The above cut has been reduced from author's original in the ratio of 1 to 2.210. To use it graphically to scale, measurements should be multiplied by this coefficient.

To obtain readings in pounds per square inch multiply real ordinates by 14.2202.

85 With these statements all the principal data are given for a turbine designed for the above mentioned normal conditions.

ANORMAL CONDITIONS

86 If the initial steam pressure is reduced from 10 *kg.-cm.*² *abs.* to 5 *kg.-cm.*² *abs.* (See p. 441.)

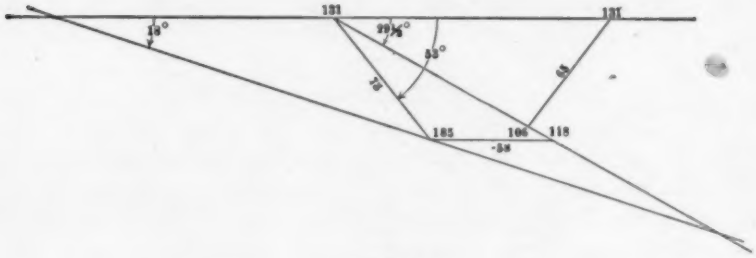


FIG. 7

To obtain readings in feet per second multiply real ordinates by 3.28

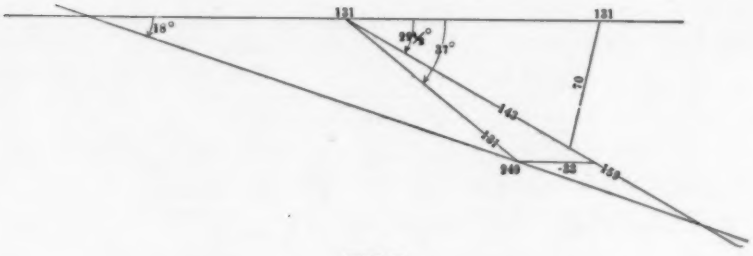


FIG. 8

To obtain readings in feet per second multiply real ordinates by 3.28

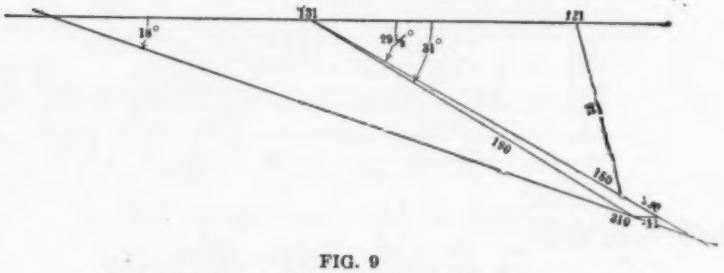


FIG. 9

To obtain readings in feet per second multiply real ordinates by 3.28

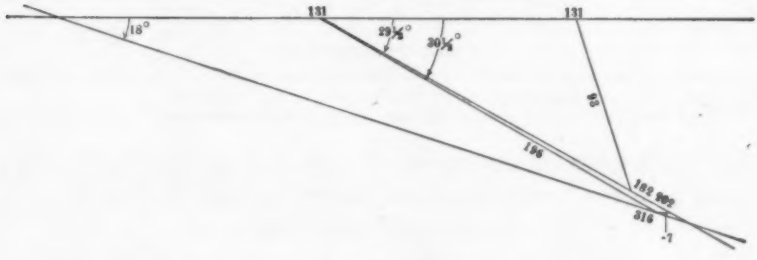


FIG. 10

To obtain readings in feet per second multiply real ordinates by 3.28

87 The exhaust pressure to remain .1 *kg.-cm.*² *abs* as before, the total available energy is hereby dropped from 70,000 *mkg.* to $427 \times 144 = 61800$ *mkg.*

88 In this logarithmical *p-v* diagram the height of the total expansion trapezium is 106 *mm.*; therefore, 1 *mm.* is equivalent to 580 *mkg.* The speed to be kept 3600 r. p. m.

89 The problem is to find out how much steam can travel through the turbine under these anormal conditions and how much power we can expect from the turbine under these anormal conditions.

90 The available main equations are:

$$c = \sqrt{2g L_u} = \frac{G \times v}{F_s}$$

With $G = .5$ *kg.-sec.* we compute the following table:

CONSECUTIVE NUMBER OF STAT. BLADE	F_{st} m^2	v *cm.-kg.*	c *m.-sec.*	$\frac{1.25c^2}{2g}$ *m.-kg. steam*	$\frac{1.25c^2}{2g}$ *m.-sec.*
10	.0345	12.8	185	2160	3.7
9	.0227	11.3	249	3920	6.8
8	.0146	9.1	310	6050	10.4
7	.0102	6.5	316	6300	10.8
6	.00675	4.55	338	7250	12.4
5	.00445	3.1	348	7650	13.2
4	.00296	2.0	338	7250	12.4
3	.00197	1.32	334	7000	12.1
2	.00129	.9	349	7700	13.3
1	.00087	.59	338	7250	12.4
				62530	107.5

With our preliminary assumption $G = .5$ *kgm.-sec.*, we arrive in the logarithmical diagram Fig. 6 at an initial pressure of 5 .07 *kg.-cm*² which is a trifle more than we ought to reach.

91 In other words, when the initial pressure is reduced from 10 *kg.-cm.*² *abs.* to 5 .0 *kg.-cm*². *abs.*, only .5 *kg.* steam can travel through the turbine, while under normal conditions 1.0 *kg.* can pass through (leakage losses in the stationary blades neglected).

92 The amounts of B.H.P. available in each running wheel (rotation losses and bearing friction losses not deducted) have to be computed same as above with the velocity diagrams:

Fig. 7 for the 10th running wheel
Fig. 8 for the 9th running wheel
Fig. 9 for the 8th running wheel
Fig. 10 for the 7th running wheel

Fig. 11 for the 6th, 4th, 1st running wheels
Fig. 12 for the 5th, 2d running wheels
Fig. 4 for the 3d running wheel

bearing in mind that the entrance and exit angles of all the running wheels are $29\frac{1}{2}°$, as designed for normal conditions.

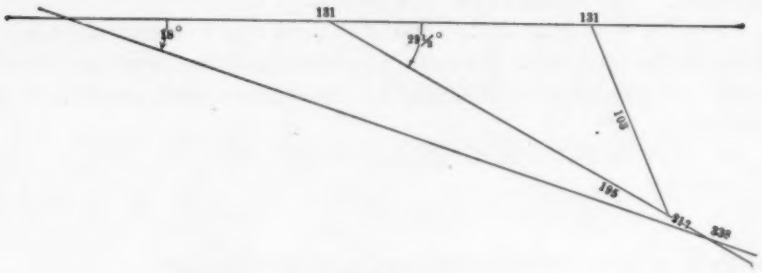


FIG. 11
To obtain readings in feet per second multiply real ordinates by 3.28

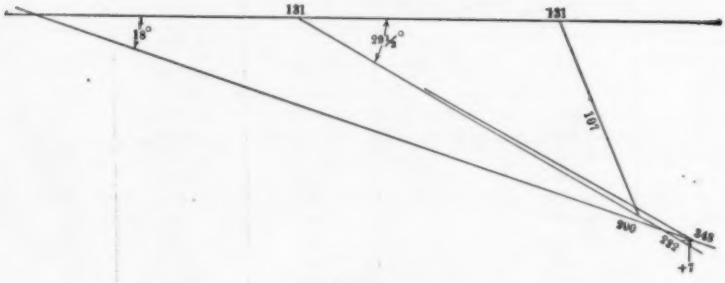


FIG. 12
To obtain readings in feet per second multiply real ordinates by 3.28

93 The following table is computed from these velocity diagrams with .5 *kg.* steam per second.

CONSECUTIVE NUMBER OF RUNNING WHEEL	AVERAGE RELATIVE VELOCITY	IMPACT VELOCITY	PRESSURES UPON THE VANES			TOTAL AMOUNT OF USEFUL ENERGY	TOTAL AMOUNT OF B.H.P
			DUE TO DEFLECTION	DUE TO IMPACT	TOTAL		
	m.-sec.	*m.-sec.*	*kg.*	*kg.*	*kg.*	*mkg.*	*B.H.P.*
1	206	+1	15.8	+.05	15.85	2080	27.8
2	211	+7	16.2	+.35	16.55	2160	28.8
3	202.5	0	15.5	0	15.5	2045	27.2
4	206	+1	15.8	+.05	15.85	2080	27.8
5	211	+7	16.2	+.35	16.55	2160	28.8
6	206	+1	15.8	+.05	15.85	2080	27.8
7	192	−7	14.8	−.35	14.45	1895	25.2
8	190	−11	14.6	−.56	14.04	1840	24.6
9	151	−33	11.6	−1.67	9.93	1300	17.4
10	112	−58	8.6	−2.95	5.65	782	10.4
							245.8

94 Which means that the total output of the turbine (rotation losses and bearing friction losses not deducted) working under these anormal conditions will be

246 B.H.P.

while for normal conditions it is

543 B.H.P.

95 Under these anormal conditions .5 *kg.* steam *sec.* are travel-

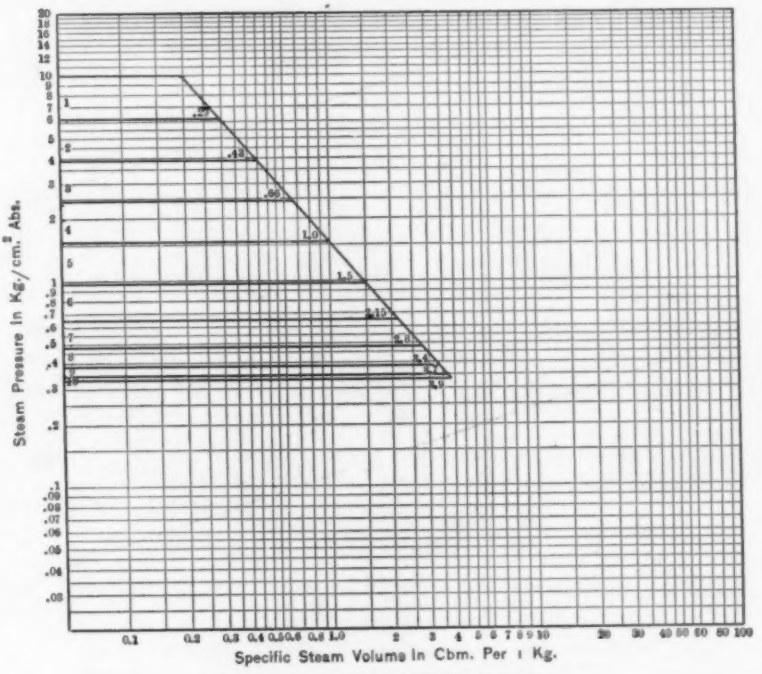


FIG. 13 LOGARITHMICAL DIAGRAM

The above cut has been reduced from author's original in the ratio of 1 to 2.252. To use it graphically to scale, measurements should be multiplied by this coefficient.
To obtain readings in pounds per square inch multiply real ordinates by 14.2202.

ing through the turbine, while before 1.0 *kg.* traveled through (leakage losses neglected).

96 Therefore, we have to expect (considering above restrictions under these anormal conditions) a steam consumption of

$$\frac{1800}{246} = 7.3 \text{ } kg. \text{ B.H.P. hour}$$

which means $$\frac{7.3 - 6.6}{6.6} \times 100 = 10.6 \text{ per cent}$$

more than under normal conditions.

97 The vacuum will drop from 27″ to 20″; or, in other words, the exhaust pressure will be increased from .1 *kg.-cm.*² *abs.* to .33 *kg.-cm.*² *abs.*

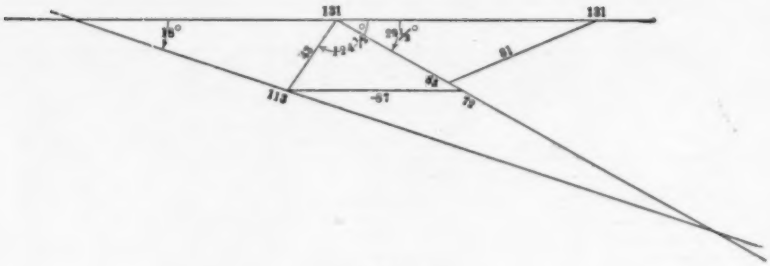


FIG. 14

To obtain readings in feet per second multiply real ordinates by 3.28

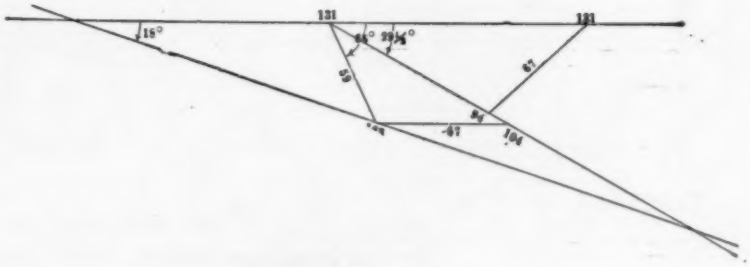


FIG. 15

To obtain readings in feet per second multiply real ordinates by 3.28

98 The initial pressure remaining 10 *kg.-cm.*² *abs.*, dry saturated steam entering the turbine.

99 The logarithmical diagram shows an available energy of only 52,000 *mkg.* = 93 *mm.* which is

$$\frac{70{,}000 - 52{,}000}{70{,}000} \times 100 = 25.7 \text{ per cent}$$

less than under normal conditions. The speed to remain constant 3600 r.p.m.

100 Applying the same considerations also for these anormal conditions we compute the following table for $G=1$ *kg. pr.* second.

CONSECUTIVE NUMBER OF STAT. BLADE	F_{st} m^2	v *cbm.-kg.*	c *m.-sec.*	$\frac{1.25\times c^2}{2g}$ *mkg.-1 kg. steam*	*mm.*
10	.0345	3.9	113	810	1.44
9	.0227	3.7	163	1680	2.95
8	.0146	3.4	232	3400	6
7	.0102	2.8	273	4720	8.3
6	.00675	2.15	319	6410	11.4
5	.00445	1.5	337	7160	12.8
4	.00296	1.0	337	7160	12.8
3	.00197	.66	334	7000	12.5
2	.00129	.43	334	7000	12.5
1	.00087	.29	334	7000	12.5
				52,340	93.1

With our preliminary assumption of 1.0 *kg.* steam per second we arrive in the logarithmical diagram at exactly 10.0 *kg.-cm.*²

101 When the exhaust pressure is increased from .1 *kg.-cm.*² *abs.* to .33 *kg.-cm.*² *abs.*, then 1.0 *kg.* steam travels through the turbine, the same as before under normal conditions.

102 The amounts of available B.H.P. of each wheel have to be computed again from the velocity diagrams.

Fig. 4 for the 1st, 2d, 3d running wheels
Fig. 19 for the 4th, 5th running wheels
Fig. 18 for the 6th running wheel
Fig. 17 for the 7th running wheel

CONSECUTIVE NUMBER OF RUNNING WHEEL	AVERAGE RELATIVE VELOCITY *m.-sec.*	IMPACT VELOCITY *m.-sec.*	PRESSURES UPON THE VANES: DUE TO DEFLECTION *kg.*	PRESSURES UPON THE VANES: DUE TO IMPACT *kg.*	PRESSURES UPON THE VANES: TOTAL *kg.*	TOTAL AMOUNT OF USEFUL ENERGY *mkg.*	TOTAL AMOUNT OF B.H.P. *B.H.P.*
1	202.5	0	31.1	0	31.1	4090	54.3
2	202.5	0	31.1	0	31.1	4090	54.3
3	202.5	0	31.1	0	31.1	4090	54.3
4	204.5	+1	31.5	+.1	31.6	4150	55.4
5	204.5	+1	31.5	+.1	31.6	4150	55.4
6	192	— 5	29.6	— .51	29.09	3810	50.9
7	166.5	—25	25.6	—2.55	23.05	3020	40.3
8	141.5	—39	21.9	—3.95	17.95	2350	31.4
9	99	—67	15.3	—6.8	8.5	1110	14.8
10	68.5	—87	10.6	—8.85	1.75	230	3.1
							414.2

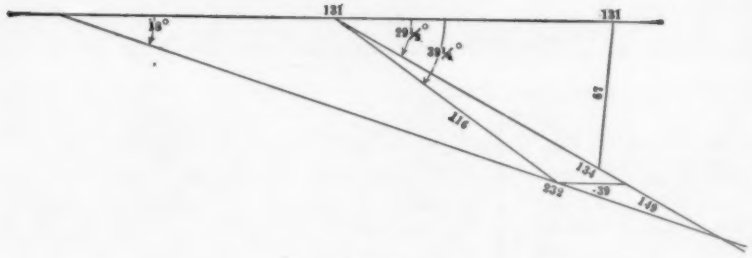


FIG. 16

To obtain readings in feet per second multiply real ordinates by 3.28

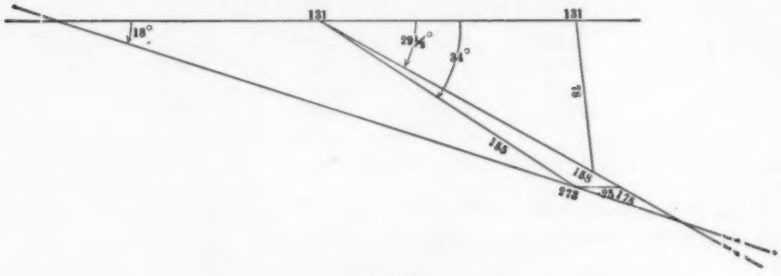


FIG. 17

To obtain readings in feet per second multiply real ordinates by 3.28

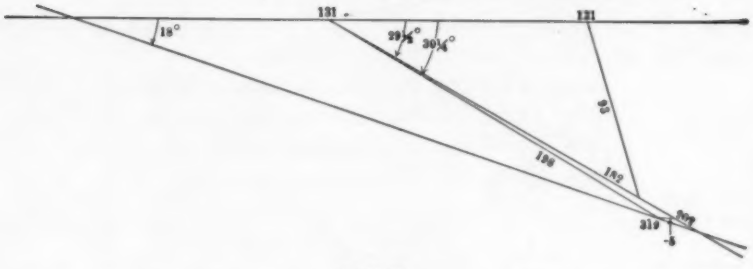


FIG. 18

To obtain readings in feet per second multiply real ordinates by 3.28

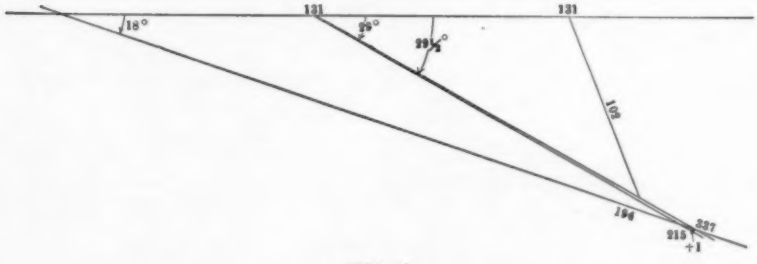


FIG. 19

To obtain readings in feet per second multiply real ordinates by 3.28

Fig. 16 for the 8th running wheel
Fig. 15 for the 9th running wheel
Fig. 14 for the 10th running wheels

103 Which means that the total output of the turbine (rotation losses and bearing friction losses not included) working with 10 *kg.-cm.*^{2} *abs.* initial pressure and .33 *kg.-cm.*^{2} *abs.* exhaust pressure will be 414 B.H.P. while it is for normal conditions 543 B.H.P.

104 Under these anormal conditions, 1.0 *kg.* steam is traveling through the turbine *pr.* second, the same amount as under normal conditions (leakage losses neglected).

105 Therefore, we have to expect under these anormal conditions a steam consumption of

$$\frac{3600}{414} = 8.7 \text{ } kg. \text{ B.H.P. hour}$$

that means $\frac{8.7 - 6.6}{6.6} \times 100 = 31.8$ per cent

more than under normal conditions.

NOTICE

106 These three specific examples have merely been given to illustrate the practical use of the logarithmical $p - v$ diagram.

107 All the computations have been made with a five inch slide rule.

CONTRIBUTED DISCUSSION

THE VENTILATION OF BOSTON SUBWAY

By Mr. H. A. Carson, Published in October Proceedings

Mr. Charles S. Churchill The Boston Subway holds the unique position of being the only electrically operated subway in the United States that is efficiently ventilated by mechanical means. The writer, in a paper on the "Ventilation of Tunnels," presented to the International Engineering Congress at St. Louis in 1904 (see Transactions, Civ. Engrs., Vol. 54, Part C, pp. 523 to 579), gave a brief description of the ventilation of the original portions of the Boston Subway; and has more recently referred to the ventilating system of this subway as a model in its careful design and execution during construction.

2 It may be further stated, after a personal examination of a number of subways in England, France, and Germany, that the ventilating system of the Boston Subway is not excelled by them in efficiency. Mr. Carson's paper, therefore, is a very valuable one as furnishing a complete detailed record of a good mechanical ventilating system of an electrically operated subway, and one that can in principle be followed, not only by existing subways not ventilated as they should be by mechanical means, but also in the case of subways to be hereafter constructed.

3 It should be noted that the ventilation of the recent extension of this subway under Boston Harbor, described as the "East Boston Tunnel," and about one mile in length, is similar in principle to that installed during the construction of the Mersey Tunnel, Liverpool, in 1886, which is about two miles in length, and is now electrically operated. The important difference, however, is that the ventilating duct is carried outside and is entirely independent of the general tunnel section from the center thereof to each end, whereas this duct in the East Boston Tunnel is cut from the tunnel area itself, thereby reducing it 48 square feet, and making it about 20 square feet less in area than the balance of the Boston double tracked sections of subway. It is considered objectionable to reduce the tunnel cross-section in this manner as just so much room for fresh air is lost. Further, the various entrances to the ventilating duct must be opened or closed frequently to suit weather conditions. In a tunnel like this, with an open portal or large opening at one end and a station at the other, not

only can the necessity of this reduction be avoided, but also the somewhat indirect handling of fresh air currents, which are interfered with either by passage of cars or by the velocity of the outside air, can be improved. Fresh air may be brought into such a tunnel at the station end without reducing the tunnel section, and from there forced entirely through it at any velocity desired, similar to the plan followed in ventilating some steam railway tunnels, for example, Elkhorn Tunnel on the Norfolk and Western Railway, Big Bend Tunnel on the Chesapeake and Ohio Railway, and Gallitzin Tunnel,[1] on the Pennsylvania Railroad; but the velocity of the fresh air current required in an electric tunnel will be but a small fraction of that required for a steam railroad tunnel.

4 Mr. Carson, while giving the parts of carbon dioxid (CO_2) per 10,000 volumes of air found in various parts of the Boston Subway when the ventilating plant was not in use, unfortunately fails to give the corresponding figures while the plant is in full operation. This information would be an important and valuable addition to the records of the ventilation of subways; and it is to be hoped that this data will be furnished, so that it may be compared with the following observations made by the writer as to the condition of air in the cars of various European subways that are mechanically ventilated.

NAME OF ELECTRIC SUBWAY	PARTS OF CARBON DIOXID PER 10,000 VOLUMES OF AIR IN CARS	PARTS OF CARBON DIOXID PER 10,000 VOLUMES AIR OF STREET
Metropolitan Railway, Paris	2.94	1.76
Central London, London	5.92	3.55
Great Northern and City Railway, London	2.35	1.75
Mersey Tunnel, Liverpool	4.70	(not taken)
City and South London, London (not mechanically ventilated)	11.78	3.55

5 Mr. Carson, after comparing the quality of air found in the Boston Subway when plant was not in operation with that found in some of the halls and schools of Boston, and noting from the comparison that worse air was found in some of the latter than in the subway, makes the suggestion that this condition "appears to justify the omission of positive ventilation in subways." It should be borne in mind, however, that carbon dioxid is not the only factor that makes ventilation necessary. In schools and halls such elements as dust from

[1]See Proceedings American Society Civil Engineers of August, 1906.

ballast, oil from machinery, iron dust from brake shoes, and heat from the conversion of large amounts of electric energy, are not present; and these elements alone may make ventilation of subways necessary. That Mr. Carson does not regard such an omission as good practice is evidenced by the fact that the Boston Subway has been mechanically ventilated. The writer doubts if any individual or corporation will argue that because bad air is found to exist in poorly designed structures used by the public, therefore, in the construction of modern buildings and subways the same degree of vitiated air is allowable.

6 There was found a few years ago in certain public halls and council chambers in London air which contained 14.9 parts of carbon dioxid per 10,000 volumes. However, newspapers of London very frequently attack subway companies in case air is allowed to even approach this condition. Further, the Factory Act of England makes 9 parts carbon dioxid (CO_2) per 10,000 volumes of air the maximum in rooms, etc., and the report of the London County Council in 1902 places the safe maximum limit of carbon dioxid in the air of any part of a subway at 8 parts per 10,000 volumes of air, and this applies to the cars in the subways.

7 Inasmuch as a subway car carrying passengers will have 45 per cent or more of carbon dioxid in excess of that found in the general subway air, this requirement signifies that the general subway air should, for the comfort of the patrons and health of the employés of the subway, be maintained so as to contain not more than about 50 per cent more carbon dioxid than the outside air. Dust should also be cared for, and the temperature of the subway should be kept within normal limits. These results, as stated by Mr. Carson, cannot be secured in any subway without positive mechanical ventilation such that fresh air is delivered to all parts thereof, and there should be added to his statement: the total furnished by natural and mechanical means should be sufficient to supply about 30 cubic feet of fresh air per minute to each person in the subway.

8 Mr. Carson very tritely remarks that the sensitive noses of the patrons of a subway readily detect the general quality of subway air. The subway tunnel of the City and South London Railway, which is not mechanically ventilated, and, therefore, is much more heavily charged with carbon dioxid than the ventilated subways of London that carry much heavier traffic, was found by the writer, as well as by others, to have a disagreeable odor. The writer in September of this year, while traversing the Rapid Transit Subway in New York, not only personally made this kind of observation, but noted from the expressions of the faces of passengers in the same

car that mental adverse comments on the quality of the subway air were being recorded. It is gratifying to note, however, that steps are evidently being taken for mechanically ventilating the New York Rapid Transit Subway.

FERROINCLAVE ROOF CONSTRUCTION

By Mr. Alexander E. Brown, Published in October Proceedings

Mr. Eugene N. Hunting The paper on fireproof roof construction as presented by Mr. Alex. E. Brown, setting forth the various merits of corrugated iron plastered with cement, brings before us a problem that nearly every engineer connected with the construction and maintenance of a manufacturing plant has to solve.

2 This problem has been worked out in about as many different ways as there have been engineers who have attempted it Some of these solutions have had merit, and more have proven worthless after a test of time and the elements. Various combinations of asbestos and cement, sheet iron and cement, concrete reinforced with rods and concrete combined with tile, have been tried with indifferent success.

3 The writer has recently had occasion to go into the subject very thoroughly, both from a practical as well as a theoretical standpoint. After a careful examination of the many systems now in vogue, an outline of the modern requirements for a fireproof roof from the standpoint of the factory engineer was drawn up as follows:

a The roof shall not weigh over 25 pounds per square foot.

b The basis of the fireproofing material shall be Portland cement concrete.

c The concrete shall be suitably reinforced by placing steel in its theoretically proper position—near the lower side of the slab.

d This roof shall be constructed in such a manner that no wood form is necessary. In light roofs the expense of a form carried at the roof elevation and supported from the ground is prohibitive.

e The cost of this roof complete and in place shall not exceed 20 cents per square foot.

f The reinforcing metal shall be of such a nature that the concrete keys into it and, in case of expansion and contraction due to rapid rise and fall of temperature, the concrete will not crack.

4 Now let us consider for a moment the various constructions that have been placed upon the market for light roofs and see what are the principal objections to their general application.

5 Let us first look at the combination of asbestos and cement in the form of tile. This tile is very light—so light in fact that it has to be wired down to keep it on the roof. The attachments are susceptible to oxidation and the general scheme has not been sufficiently used to prove conclusively whether the combination will stand the test of the elements.

6 The next proposition that comes to mind is the light cement tile. This also has its limitations; it is hard to keep the roof dry and almost impossible to keep the shingles from cracking, both of which are due to changes in temperature.

7 Let us now consider the solution of the problem, as presented by Mr. Brown, by the use of Ferroinclave and see how it meets the requirements. It is light, cheap and easily applied. However, there are several points about it that do not appeal to an engineer—at least one that is familiar with the theories and methods of reinforced concrete designers.

a In the first place the sheet metal of Ferroinclave or Ferrolithic tile is not a true reinforcement for the concrete. The entire metal section lays very close to the neutral axis.

b There is no real key between the plaster and the metal except the interior angle of the metal.

c The writer could not conceive of Ferroinclave or Ferrolithic tile acting in a severe fire and water test much better than corrugated iron.

8 It is quite evident to one familiar with the expansion of steel and concrete that in a severe fire the cement would spall from under the side of Ferrolithic tile. Also that on the application of water to the heated metal on the under side, the contraction of the metal would destroy all adhesion of the concrete and steel and the roof would fall. The writer believes that Ferrolithic would stand up well and serve its purpose when subjected to ordinary temperatures. However, in most cases it is not the small fire that we are trying to protect ourselves from—it is the fire that starts at one end of the plant and threatens to destroy all. This is the time when fireproof protection must be something more than a name or a theory; it must be true protection in a most serious conflagration.

9 The writer will endeavor to describe briefly in the following

paragraphs a roof construction that he considers will meet every argument and give proper fire protection in every sense of the word.

10 Figs. 1 and 2 show "Herringbone Truss Lath" and its application to light fireproof roof construction.

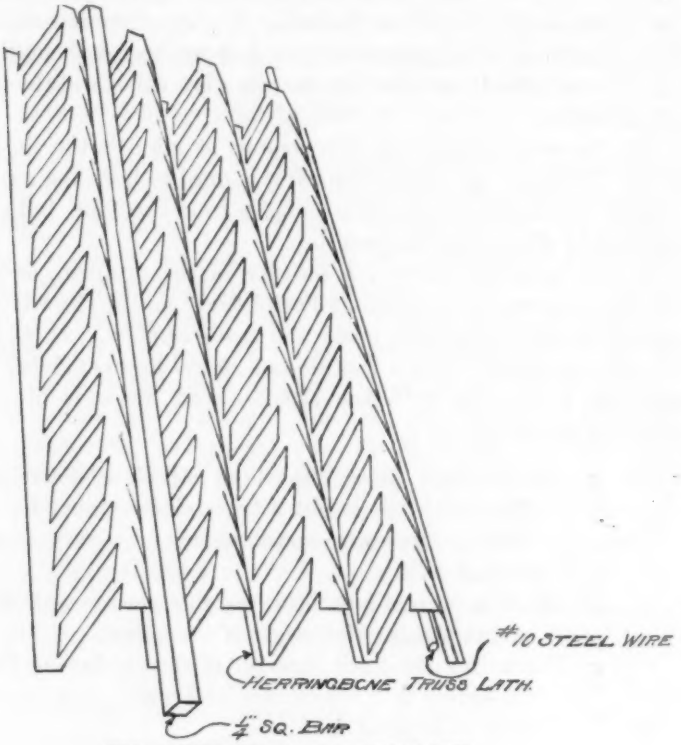


FIG. 1 HERRINGBONE TRUSS LATH

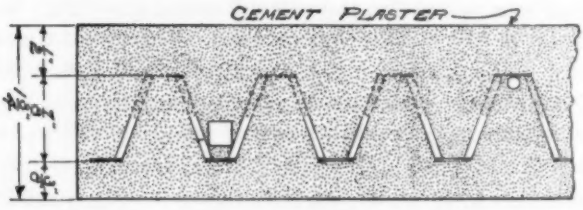


FIG 2 APPLICATION OF HERRINGBONE TRUSS LATH TO LIGHT FIREPROOF ROOF CONSTRUCTION

11 The method of construction is very similar to Ferrolithic work. The lath is stretched from one purlin to another on small wires and is lapped at the joints. A coat of cement plaster is applied to the top and another to the bottom, the lath acting as a true reinforcement.

This roof will carry all ordinary roof loads with a factor of safety of four on a three to four foot span. For heavier loads small iron rods are inserted running up and down the valleys of the Herringbone.

12 The cement mortar is thoroughly reinforced in both directions and has a perfect key. It can not spall when under severe fire and water tests because of the peculiar section of the metal. To substantiate this statement, the writer wishes to call attention to the fact that after the New York Building Department fire test on this material, examinations showed that the plaster was as securely locked in the key of the lath after the fire as before it was started. A heat of 1700° was maintained for two hours and the slab was subjected to fifty pounds of water pressure. There was no sign of cracking or movement of any kind—there could not have been a more severe test, nor could the result have been more satisfactory.

13 A remarkable feature, and one that appeals to the constructor as well as the engineer is the low unit cost of this construction. The cost of the roofing in place runs from 18 cents to 20 cents per square foot, depending upon the labor conditions.

14 The writer is of the firm opinion that in the near future practically all fireproof roof construction designed for light loads will be built on a self-centering, open reinforcement such as trussed Herringbone or its equivalent.

SAW-TOOTH SKYLIGHT IN FACTORY ROOF CONSTRUCTION

By Mr. Fred S. Hinds, Published in October Proceedings

Prof. John E. Sweet I am led to comment on Mr. Hinds' paper more to correct some mistakes than with an idea of adding much to its value.

2 In 1889 the weaving shed roof of the Straight Line Engine Company's Works in Syracuse was built, and I supposed at the time and until the appearance of Mr. Hinds' paper that it was the first application in this country of this form of roof to machine shop use.

3 As a full account of this roof was given on pp. 527 to 535 of the Transactions for 1893, I have only to add that it is on the English plan and without the troubles Mr. Hinds mentions, and this was obviated by making the gutters of cast iron, short enough to go between the trusses, which are only 8 feet centers, and draining each trough by a separate spout into a continuous conductor running from end to end of the building. As the troughs and conductor are inside the building and are of iron instead of wood they melt out the snow and ice before it melts on the roof and hence there is no trouble from freezing ice and

snow. The troughs being in sections with a proper joint cover, expansion and contraction have no detrimental effect. So satisfactory have been our 17 years of experience, that the same system has been adopted for the Artisan School.

4 The spans are 32 ft., trusses 8 ft. apart and the glass 6 ft. high. During the 17 winters, snow has never had to be shoveled off but once and then only because it piled up on the glass and shut out the light. In the ordinary machine shop the lower chord of the truss has, in addition to acting as a chord, another function to perform, that of carrying the line shaft and counters and two angles spaced $\frac{5}{8}$" or $\frac{3}{4}$" apart between which supporting bolts will pass, making a far more convenient arrangement than to screw coach screws into the wood girders. Concrete for this service would appear to be especially bad where shafting has to be supported. With our experience I would be as reluctant to adopt the other form as Mr. Hinds would be to adopt ours. Any kind of metal gutters if properly made will work all right if inside the building.

5 It is common practice to put trusses 16 to 20 or more feet apart with purlines from truss to truss, then rafters and planking. Light trusses, eight or at most ten feet apart are better for several reasons. The purlines and rafters are dispensed with, two light trusses have less to carry than the one heavy one, they are more easily constructed and erected, and with the close spacing they are right for line shaft hangers without stringers.

6 It is claimed by the constructors of structural steel buildings that the large trusses and wider spacings are cheaper and the better method, but they can be just as easily mistaken as anyone else, or at least for spans of 30 or 40 feet. I am satisfied that when considering the advantages pointed out above they are dead wrong.

MACHINE SCREW REPORT

PUBLISHED IN OCTOBER PROCEEDINGS

THE SECRETARY The Association of Licensed Automobile Manufacturers sometime ago appointed a Committee on Standard Hexagon Screws and Hexagon Nuts to consider a new screw standard to overcome, if possible, the inconvenience occasioned by the number and variety of special threads and nuts used in the automobile trade. This committee consisted of A. L. Riker, H. E. Coffin, H. P. Maxim, Charles B. King, John Wilkinson, Russell Huff and Henry Souther.

The "Association Bulletin," No. 18,[1] embodying the report of this

[1]A copy of this Bulletin can be obtained upon request to the Association of Licensed Automobile Manufacturers. 5 East 42d Street, New York, N. Y.

Committee, says: "During recent years, however, manufacturers of fine machinery have found from experience that for a large portion of their work the United States standards for pitch of threads have been too coarse, and the dimensions of heads and nuts too large. In order to secure satisfactory construction special fine pitch screw threads and smaller nuts have had to be made.

"It is assumed that where screws are to be used in soft material, such as cast iron, brass, bronze or aluminum, the existing United States standard pitches will be used. The term 'screw' is intended to supplant the present so-called 'coupling bolt' and 'cap screw.' The term 'plain hexagon nut' is intended to supplant the present so-called 'United States standard nut.' The term 'castle nut' is given to a new nut, which is intended to be used where a positive locking system is desired. The term 'facing' is given to a relieved portion under the screw heads, castle nuts and plain nuts."

The detailed dimensions and specifications of the screws, castle and plain nuts recommended, from one-quarter ($\frac{1}{4}$″) inch to one (1″) inch inclusive, are shown in the cuts published in the "Bulletin."

This report is accompanied by the following specifications:

MATERIAL

A better material than ordinarily used for screws is deemed necessary. The selection of a better material depends to a considerable extent upon the possibility of commercially machining it in screw machines. Such material has been found in several qualities of steel having a tensile strength of not less than one hundred thousand (100,000 lbs.) pounds per square inch, and an elastic limit of sixty thousand (60,000 lbs.) pounds per square inch, as compared with fifty or sixty thousand (50,000 or 60,000 lbs.) pounds per square inch tensile strength and thirty-five thousand (35,000 lbs.) pounds per square inch elastic limit now in common use. The screws and nuts described in this standard are to be made of this better material. Screws are to be left soft. Screw heads are to be left soft. The plain nuts are to be left soft. The castle nuts are to be case-hardened.

TOLERANCE

The body diameter of the screws shall be one-thousandth (.001″) inch less than the nominal diameter, with a plus tolerance of zero and a minus tolerance of two-thousandths (.002″) inch. The nuts shall be a good fit, without perceptible shake. The clearance between tops of threads and bottoms of threads in nuts shall be that existing in the present practice of machine screw makers; that is, the tap shall be between two-thousandths (.002″) inch and three-thousandths (.003″) inch large.

LENGTH OF THREADED PORTION

The threaded portion of screws shall be one and one-half ($1\frac{1}{2}$) the body diameters.

The cut and table below give in summarized form details as to the screws and nuts:

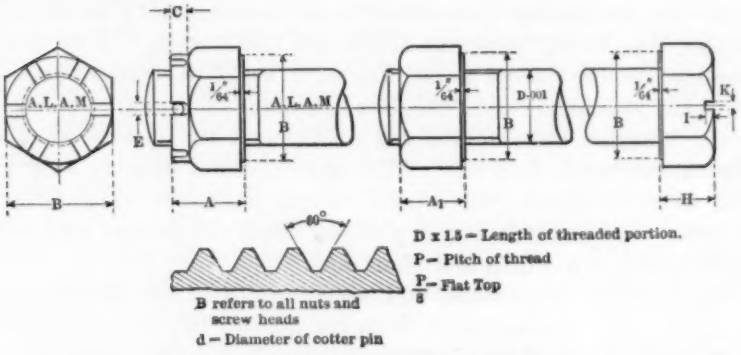


FIG. 1 DETAILS OF SCREWS AND NUTS

TABLE OF DIMENSIONS OF SCREWS

D	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	1
P	28	24	24	20	20	18	18	16	16	14	14
A	$\frac{9}{32}$	$\frac{21}{64}$	$\frac{13}{32}$	$\frac{29}{64}$	$\frac{9}{16}$	$\frac{29}{64}$	$\frac{33}{32}$	$\frac{49}{64}$	$\frac{13}{16}$	$\frac{29}{32}$	1
A	$\frac{7}{32}$	$\frac{17}{64}$	$\frac{21}{64}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{21}{64}$	$\frac{25}{64}$	$\frac{19}{32}$	$\frac{21}{32}$	$\frac{49}{64}$	$\frac{7}{8}$
B	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{7}{16}$
C	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
E	$\frac{5}{64}$	$\frac{5}{64}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{5}{32}$	$\frac{5}{32}$
H	$\frac{3}{16}$	$\frac{15}{64}$	$\frac{9}{32}$	$\frac{21}{64}$	$\frac{3}{8}$	$\frac{27}{64}$	$\frac{15}{32}$	$\frac{33}{64}$	$\frac{9}{16}$	$\frac{21}{32}$	$\frac{3}{4}$
I	$\frac{3}{32}$	$\frac{7}{64}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
K	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$
d	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$

All dimensions in inches. All heads and nuts to be semi-finish. Material for all screws and nuts—steel, tensile strength, not less than 100,000 lbs. per square inch, and elastic limit not less than 60,000 lbs. per square inch.

FORM OF THREAD, UNITED STATES STANDARD

DIAMETER	PITCH	LENGTH OF THREADED PORTION	DIAMETER OF HEAD ACROSS FLATS	THICKNESS OF HEAD	DIAMETER OF FACING UNDER HEAD	DEPTH OF FACING UNDER HEAD	WIDTH OF SLOT IN HEAD	DEPTH OF SLOT IN HEAD	DIAMETER OF COTTER PIN HOLE
1/4	28	3/8	3/8	3/16	3/8	1/64	1/16	3/32	5/64
5/16	24	15/32	1/2	15/64	1/2	1/64	1/16	7/64	5/64
3/8	24	9/16	9/16	9/32	9/16	1/64	3/32	1/8	1/8
7/16	20	21/32	11/16	21/64	11/16	1/64	3/32	1/8	1/8
1/2	20	3/4	3/4	3/8	3/4	1/64	3/32	1/8	1/8
9/16	18	27/32	7/8	27/64	7/8	1/64	3/32	1/8	5/32
5/8	18	15/16	15/16	15/32	15/16	1/64	3/32	1/8	5/32
11/16	16	1 1/32	1	33/64	1	1/64	3/32	1/8	5/32
3/4	16	1 1/8	1 1/8	9/16	1 1/8	1/64	3/32	1/8	5/32
7/8	14	1 5/16	1 1/4	21/32	1 1/4	1/64	3/32	1/8	5/32
1	14	1 1/2	1 7/16	3/4	1 7/16	1/64	3/32	1/8	5/32